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CHEMISTRY AND PHYSICS

IN THE HORACE MANN HIGH SCHOOL[1]

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INTRODUCTION

"Science is not solely for the men of science but for the people."
— T. H. HUXLEY

If the phrase, "A self-respecting course in physics or chemistry," means one adapted only to the few, the courses herein described are not intended to come in that category. We believe that physical science should be so taught in the high school that all pupils can pursue it with pleasure and profit. It should be something more than *measurement* and something more than mathematics, pure and applied.

Those who would prescribe work in science for the high school must have just as thorough knowledge of the pupils as they have of the science.

[1] Chemistry and physics are taught to a considerable extent in the Elementary Department of the Horace Mann School. The topics are scattered through the courses in Nature Study and Geography. For the details of the course in Nature Study see Vol. I. No. 2 of TEACHERS COLLEGE RECORD, published in March, 1900; and for the course in Geography see Vol. II. No. 2 of the RECORD, published in March, 1901. The present number of the RECORD deals only with courses in Chemistry and Physics in the High School, with the exceptions mentioned on pp. 43–50.

In certain quarters physical science is suffering most at the hands of its friends. Persons devoted more to the science of the subject than the science of the pupil are pursuing a method of work which repels the pupils and dissatisfies the parents. Pupils at the age of fourteen or fifteen come to the study of chemistry and physics with enthusiasm, if they can find some one willing to teach them what they want to know in order to live contentedly in a world that is bristling with physical phenomena. Too often high-school pupils are put off until the latter years of the high-school course; and then the teachers, fearful lest their work may be stigmatized as unscientific or superficial, dare not give them more than the grammar of the subject. What excuse is there for the idea that nothing must be taught unless it can be taught thoroughly, or, for that matter, unless it can be taught correctly! Those who do not know that their facts are subject to revision are unsafe teachers and certainly are not to be classed among the scientists. Meanwhile the teachers of other departments have, with more of the spirit of missionaries and with more of the wisdom of educators, innoculated these pupils and absorbed their interests until they have become insistent upon lines of study and habits of thought quite remote from those of physical science. It thus happens that although physical science is very much in the ascendency in the world it is still very much neglected in many of the schools.

The apathy for all branches of science among pupils even of the high-school age is a real thing, but a thing for which parents and teachers are to blame. It is displaced by enthusiasm in the case of pupils who are introduced early to laboratories.

The principal thought in the minds of those who have planned the courses in chemistry and physics for the Horace Mann High School has been to provide work in these subjects suited to the need of the average pupils, boys and girls, without special requirements of previous training either in mathematics or other sciences, and as early in the high-school course as possible. In point of fact, chemistry is taught in the first year and physics in the second year of the high-school course. The question will naturally arise, Do these courses fit for college? The answer is that more than 80 per cent of the pupils of the Horace Mann High School do fit for college, and a good portion of them offer chemistry and physics for entrance

examinations. During the thirteen years that these courses have been in operation a large number of boys and girls have passed from them into all the leading colleges in the East. However, we believe these courses aim at something more than fitting for college. They are planned to meet the needs of those boys and girls who are inquiring into the phenomena of the physical world about them.

The undercurrent of our thoughts while planning and executing these courses is indicated by the following phrases contributed to this paper by the workers in the department in response to my request for a statement of what seemed to them to be our guiding thoughts. (It is of course understood that we claim no monopoly, but are laboring in common with many other departments toward the same end or ends):

"Awaken interest in natural phenomena — the significance and importance of such phenomena, and the explanation of those which are most familiar."

"Satisfy the love of the novel and wonderful."

"Observe and think about what one observes — the classroom exercise being a small part of the process."

"Organize every-day observations — Associate facts — Light up one fact by another."

"Observe facts — compare with other facts — recognize laws which govern them — Formation of scientific habit of thought."

"Develop the powers of induction and deduction."

"Think logically and draw correct conclusions — form accurate judgments — Ability to weigh evidence."

"Ability to distinguish between the true and the false — Create a desire for the truth — Conservatism — Open-mindedness — Distrust of imagination when untempered by reason."

"Interpretation of Nature — We are limited on all sides by physical laws. We need to understand them so that we may not undertake physical impossibilities. We make unreasonable demands — We make ourselves and others unhappy by not knowing and not yielding to the inevitable — The reign of natural law."

"Ability to act on contingencies — Training in prudence and foresight."

"Executive ability — Self-confidence — Dexterity."

"Skillful manipulation a mental training."

"Concentration — Accuracy — Patience — Carefulness — Neatness."

"Constructive imagination."

"Stimulate, by laboratory work, powers of imagination and invention."

"Draw the attention away from the abstract to the practical."

"Applied mathematics — Contact with machines — Common sense."

"Fit for life — Open a field in the economic world — Knowledge of physical science in every profession and business. Adoption of scientific method in everything."

"Clearness of thought and expression — Use of exact and terse English."

"Furnish a fund of valuable information."

"Broadening one's views of life."

"Aid in general culture."

"Physical science lends itself readily as an instrument for illustrating the best pedagogical principles."

The above list is submitted not as a record of work done, but as the object of our desires.

Our Reasons for Putting Chemistry before Physics. — During the first few months of high-school work in science special attention should be given to training pupils in good laboratory habits, and pupils in the early part of the high-school course are at the right age — about thirteen to fifteen years — to begin to learn the mechanical side of laboratory work. For this purpose I prefer chemistry in the first year, followed by physics in the second year. It is possible to put nearly all of the chemical apparatus in the hands of each pupil. Test tubes, beakers, and flasks constitute most of this equipment, and need not cost more than two or three dollars per pupil. This is not true of physics. No one expects to have physical apparatus enough to supply each member of his class with every piece, and hence the pupil in physical laboratory work must be a little more capable of self-direction on that account. The mechanical part of laboratory work in chemistry may, and I believe it should be, made simpler than that of physics. When the experiments are

going badly in the laboratory, as they frequently will with beginners, the teacher performs an experiment in the presence of the class, discussing the difficulties as he proceeds, and when he has finished has them all try the same experiment. In this manner he trains the pupils to do things as they ought to be done and to see things as they are. We teach them to bend a delivery tube that approaches pretty closely to some model taken as a standard. We train them to transfer powders to test tubes without getting any upon the tables, or even upon the sides of tubes; to invert a bottle of water for catching gases without admitting any air; to heat test tubes and flasks without breaking them; to use acids without spotting the tables or the clothing or the labels upon the bottles; to generate chlorine, hydrogen sulphide, etc., without contaminating the air of the room. If they are not so trained when they are quite young they are hopeless. The college professor who gets hold of a lot of careless students finds that he is quite helpless. He can do very little toward reforming their laboratory habits. Indeed, while the first high-school class will submit very willingly to this training in painstaking, careful habits, the third and fourth year pupils are already getting beyond that stage.

2. We put chemistry before physics, not only because it enables us better to introduce young people to laboratory methods so far as the mechanics of these go, but also because it may, and we believe it should, be treated as a simpler subject than physics with reference to training in thought power. The high-school text-books in chemistry are simpler than those in physics. It is true that portions of both subjects are not understood by the pupils. Most of the portions of chemistry, however, which the first-year high-school pupils do not comprehend will not be comprehended by the fourth-year high-school pupils either, and these portions may very properly be left for the college course. Chemical theory has very little place in the high school in whatever year the subject is taught. We treat the subjects so that *combustion* in chemistry is simpler than *heat* in physics; the *chemistry of water* simpler than the *mechanics of fluids;* the chemical conduct of chlorine, sulphur, nitrogen, carbon, etc., simpler subjects of study than electricity and sound. I find that chemistry lends itself very readily to the training of young pupils of thirteen or fourteen years of age, not only in the mechanics of the laboratory,

but also in the more important process of making experiments lead to orderly thought. Pupils of that age can be readily taught all the chemistry necessary to fit for college, so that we are not hampered by that consideration. The work is certainly no more difficult than the algebra which they are taking the same year.

3. The books that we wish the pupils to read in connection with their work in physics all come under the head of applied science. Such books invariably have the subject matter of chemistry and physics commingled. A sufficient number of them are well adapted to the attainments of our second-year high-school pupils. They would have little connection with a course in chemistry, but they are an important part of a course in physics for those who have had an elementary course in chemistry.

Scientific Observing. — The great aim of science teaching is to accustom the mind to logical arrangement; to make one thought grow out of another; to so arrange things that one phenomenon shall appear in its relation to another; so that one fact may throw light upon another; to organize our every-day observations. A person thinking much on some question, the answer for which he expects to find in nature, is liable to see things which cast light upon his problem, while at the same time he may be very unobserving of those things which do not help toward the answer of his question. This is scientific observation. Children are natural observers. They only need to be taught to select for a definite purpose, and to connect one observed fact with another. This, I imagine, is what Professor Huxley meant when he said, " Science is merely organized common sense." The number of observations which a person may make in a given time is often inversely proportional to the amount of thinking he does. A child and his father go to walk. By the roadside they both notice some object as they pass along. The father, having had a wider experience, finds something in this object which starts a train of thought. The child, not being so occupied, sees numerous other objects which the father fails altogether to notice, or, if he does notice them, they flit across his mind without making any impression; but presently an object attracts his attention, and because it is related to the first it attracts his attention more than it does that of the child. The number of objects seen by the child during that walk may be vastly more than the number seen by the father, but the father has seen related things; he has

seen to some purpose; he, of the two, is the scientific observer; yet, if some one asks whether they passed a certain gate, the boy will be likely to be the only one who can answer. Now, no teaching can enable the boy to see more things, but training may enable him to think more about what he sees. Some one has said that a good memory requires a judicious forgetfulness; so scientific observation requires that the mind shall not be distracted by observing a multitude of unrelated things.

Chemistry and Physics as a Key to the World of Science. — Elementary chemistry and physics furnish simple inductions. We may select our facts in physical science and arrange them so as to make the conclusions to be drawn from them as simple as we choose. Nature performs many physical experiments in a large way — too large for the youthful mind to encompass. We may perform in the laboratory experiments which represent the large phenomenon piecemeal, and thus build up the conception of the whole, and at the same time develop the constructive imagination which is needed to grasp the processes of nature. Often we may devise for the laboratory a miniature representation of the larger phenomenon of nature which shall be quite a perfect analogy. This not only shows the possibilities of laboratory work in chemistry and physics, but I believe it indicates in a general way a very important aim to be kept in view, viz., to select as far as possible such work as should prepare the way for the contact with physical science in life and particularly with such matters as city water and gas works, heating and ventilation of buildings, the uses of steam, electricity, etc. See Excursions, pp. 43-50.

As a result of these courses and those in Manual Training, to which they are closely allied in spirit, pupils become more self-dependent in mechanical matters and save themselves and others much loss and annoyance. Their parents testify that whereas it used to be necessary to send often for an electrician to adjust the electric bells about the house, their children have now learned the few simple things necessary to be done to keep them in good order. They put new washers upon leaking water faucets. They replace nuts which have come off the handles of bureau drawers, and screws that have fallen out of the door knobs. They read the water meter and the gas meter. They understand the mechanism of the furnace and their special instruc-

tion about what to do in case of fire has resulted in the prompt extinguishing of several fires in the homes that gave promise of being very disastrous. They are more generally useful than formerly and some new interests have been added to their lives. If they grow up to be masters, they will more wisely direct their servants because of their better understanding of these practical matters and will probably have fewer "servant problems" on that account.

If the high-school instructor in chemistry and physics would perfect himself he must take in addition to ample courses in pure science, as many courses as possible in applied science and come much in contact with the business life of the world.

THE RELATION OF HIGH-SCHOOL WORK TO COLLEGE WORK. — While we regard the high-school work in chemistry and physics an almost essential preparation for the general courses in chemistry and physics in college, they are not planned to complete any portion of the subject so as to make college work in that portion unnecessary. So far from the high-school work in chemistry and physics taking the interest out of the college work, it increases it fourfold, and, so far from its creating in the student bad habits either of doing or thinking, which will require to be corrected in college, it begets habits essential to good work in college; and if the pupils fail to receive this training in the high school it is very difficult for the college instructor to accomplish wholly satisfactory results with them.

There is no objection to giving high-school pupils a general view of chemistry and physics even if they are going over the same ground again in college. On the contrary it is in every way advantageous so to do. All the great principles of chemistry and physics have entered the mind of the race in that way. "Contemporaries were at first little impressed with the truth, self-evident though it may now appear to all men." It had to be repeated and sometimes rediscovered.

CORRELATION WITH OTHER SUBJECTS. — We expand quite fully those topics which appeal most to the pupils. Such topics are wrought out to the fullest extent in their application to physical geography, meteorology, astronomy, biology, physiology, cooking, the phenomena of the kitchen, the factory, the shop, the farm, etc. This is not intended to interfere with the more extended study of physical geography, physiology, cooking, etc..

afterwards. It gives the best possible introduction to them, and at the same time makes the chemistry and physics mean much more than they otherwise would. These subjects are too often treated like a course in grammar. Too much attention is given to learning the definitions of things not immediately useful.

Relation of Laboratory, Recitation, and Lecture. — As a rule laboratory work goes hand in hand with lectures and recitation work, otherwise neither could be brought to fruition. Laboratory work is too often merely mechanical. Students may become adept at working with instruments of precision without gaining any outlook upon physics, without acquiring any habits of induction, or the faculty of seeing relations. I take it that the training of the constructive imagination is equally important with training in accuracy. Our idea of the relation of laboratory, text-book work, and lecture I have stated in New York Regents' Bulletin No. 42, published in 1897, and quote it here:

"The Laboratory. — The chief purpose of the laboratory, in the high schools at least, is not for the exercise of the inductive method. Fascinating and fruitful as that method is in the hands of a few ripe scholars, it is often a snare and a delusion in the hands of the young or of the untrained adult. With great care pupils should be trained in the process of induction for its own sake, but not with the idea that that is the method by which they are to be taught any considerable portion of science. There is small chance for induction in the teaching of high-school chemistry or physics. Mechanics and light furnish the best opportunity for the use of that method. The chief purpose of the school laboratory should be to make knowledge real. Merely to see a piece of apparatus aids immensely one's appreciation of the physical principle which the apparatus illustrates, but when one manipulates the apparatus himself he acquires a knowledge of physical science which he can in no other way attain. In order that a laboratory exercise may be productive of good, two things must be looked out for; first, the pupil's mind must be carefully prepared for it beforehand. Nothing is more common than to find pupils going through their laboratory exercise in a mechanical way without acquiring much knowledge of the physical principles involved; and second, the pupil's mind must be guided to some definite end. This in most cases can be done by quizzes following more or less closely the laboratory exercises; but fre-

quently, to prevent desultory and aimless work, it is necessary to conduct quizzes either of individuals or of the whole class during the laboratory exercises. High-school pupils cannot with profit be left much to themselves in laboratory work. They need very specific written or printed directions. They must also have a discreet teacher, who will keep very busy supervising the work of each pupil while in the laboratory.

" Laboratory work is so apt to be a blind following of directions without much thought upon the relation of the work, that we find it necessary to sprinkle among written directions a great many queries and problems intended to lead the pupil out from the observation upon the individual experiment in hand to kindred observation in other experiments or in nature, that he may acquire the habit of looking for relationships and of making broader generalizations.

" Laboratory work requires as good solid thought as does a recitation; indeed, there must be considerable of the recitation feature about it. To accomplish this the division must not number more than twenty-five, and the instructor must have an assistant capable of helping in his work of going about among the pupils while at their work, and giving the right kind of guidance and of asking the right kind of questions. This assistant is also assigned the large and important task of examining critically the pupils' laboratory note-books, and discusssing with each pupil such matters as need correction.

" THE TEXT-BOOK. — The earlier text-books were faulty in that they covered too wide a range of subjects and dealt too much with paradoxes. They seemed in many cases to be a deliberate attempt to make things seem unnatural and unreal. There was the hydrostatic paradox and the culinary paradox, the Cartesian diver or bottle imp, the ' fountain in vacuo,' the ' Hero's fountain,' the ' Bacchus illustration,' the ' bolt head,' etc. These were the topics around which the instruction centered, and these formed the items of examination questions. The text-books to-day have discarded much of this material, but they have become extremely meagre and uninteresting. They still deal with too many principles, but treat them too meagerly. A principle is stated in a brief paragraph. This paragraph is followed by a description of a single experiment, and then another principle is served up. In many cases that which occupies half a page might better be

expanded to cover a dozen pages. Silvanus Thompson's *Elementary Lessons in Electricity and Magnetism* illustrates fairly well a good form of expansion of the text. But in addition to such matter as is to be found in this book, and perhaps with the elimination of some of it, I should recommend filling out the text-book with what might be called adipose tissue — the abundant illustration of each principle with well-told incidents in every-day life — something calculated to make the pupil see physics in the world around him. Such expansion of the text-book might make it necessary to have it bound in several volumes. The pupil has an armful of books for Greek or history or English; why not for physical science? It must be so if the latter is to take its place among the former as a disciplinary and a culture study. As in history or English so in physical science, there must be extensive use of the library. Topics should be assigned which require the student to consult books of reference, not merely for tables of boiling points, etc., but the reading of magazine articles, of encyclopedias, and of volumes like Faraday's *Chemical History of a Candle* and Tyndall's *Forms of Water* and *Heat a Mode of Motion.*

"There should be beside text-books and books of reference a laboratory manual containing very specific directions for the work to be done in the laboratory, a great deal of information concerning apparatus and experiments, a great many queries, mathematical problems, and supplementary exercises, etc. This book should be well supplied with blank pages upon which the pupil may disclose the state of his own mind.

"THE LECTURE. — A strong feature of good instruction in physical science is the lecture. The teacher of physical science should aspire to some reputation as an interesting lecturer. He has the best possible subject with which to attract an audience; why should he neglect the opportunity to interest and instruct and inspire by this method? Let him not despise the giving of university extension lectures for the good it may do himself. If he has learned how to enjoy the study of physical science in the laboratory, in the library, and in nature, let him inspire his students by giving them through his illustrated lectures a glimpse of his own broader view upon the subject. By lectures he can make physics and chemistry real, live subjects as nothing else can possibly do."

There are certain chapters in physics which must be treated chiefly in lecture and recitation; the laboratory work plays only a small part. There are two means of adjusting in such cases; first, we use some of the laboratory period for extra lectures and recitations; and second, we introduce some laboratory work which, although needful, may be irrelevant. This is the case in the early part of the course, where the laboratory work is upon the metric system and mensuration, while the lectures and recitations are dealing with properties of matter, gravitation, motion, etc. During a portion of the study of heat and sound the time of lectures and recitations is increased at the expense of laboratory work. During a portion of the study of the dynamics of fluids and electricity the laboratory work is increased at the expense of the lectures and recitations.

SYLLABUS OF THE COURSE IN CHEMISTRY

TIME. — First year of the high-school course. Pupils about fourteen years of age. One year of thirty-two weeks. Two exercises of forty minutes each and one exercise of eighty-five minutes weekly, with two hours of home study, making four hours and forty-five minutes each week. One period of forty minutes is devoted to a lecture when all the divisions of the class meet together in the large lecture room. The period of eighty-five minutes is given to laboratory work and the remaining period of forty minutes is devoted to recitation, or, in some cases, to extra laboratory or lecture work as the subject may demand.

THE CHEMICAL LABORATORY. — Each pupil has assigned to him in the laboratory a desk with a drawer or cupboard. Running water and gas are at hand, a stone jar under the desk for such waste material as cannot be removed by the waste pipe. The sinks are of the ordinary household type of porcelain bowl. The tops of the tables are oak finished with wood filler and oil. The laboratory training is intended to teach the uses and limitations of waste pipes and the proper care of tables. Laboratory hoods are provided for such experiments as would vitiate the air of the room. Reagent bottles are not allowed to stand continually upon the laboratory tables. They are kept in a case, and are distributed about the tables upon asbestos mats for each exercise in which they are required. It is intended that the laboratory shall be as attractive as the library and its decorations will some day be as complete.

When the pupil first reaches the laboratory he finds the material for most of his apparatus in his drawer and cupboard, with a printed list giving the name of each piece. This material is committed to his charge as specified on the bill. He may draw more from the stock room as he needs it, which will also be added to his account. There is a teacher's desk at one side of the room, around which supplementary lectures are given and recitations are conducted. A working shelf runs along one side

of the room underneath the windows, where electric current is supplied and where the balances are placed when there are to be experiments in weighing. Cases are provided for reagents, chemicals, exhibition apparatus, books, etc.

For text-books we use Remsen's *Elementary Course* and Woodhull and Van Arsdale's *Laboratory Manual.* Definitions and chemical principles are brought in rather incidentally but recurrently throughout the course whenever good illustrations arise to enforce them.

In this manner the following matters are taught in gradual sequence of development, and after they have been once introduced they are taught repeatedly, so that they are not easily forgotten: chemical nomenclature; symbols; formulas; reactions and equations; definite proportions; oxidizing and reducing agents; atoms and molecules; effects of light, heat, electricity, and solution upon chemical action; mechanical mixtures and chemical compounds (acids, bases, and salts); valence; the nascent state; indestructibility of matter; combining weights.

Oxygen and the Air. — The first month is devoted to the study of oxygen. In this case, as frequently throughout the course, a lecture introduces the laboratory study of the subject, and other lectures follow the laboratory work. By the end of the month we expect the pupils to know that oxygen makes many things burn; things which burn in the air burn more readily in oxygen, but the result appears to be the same; some things which do not burn in air burn readily in oxygen; in the atmosphere oxygen is mixed with other gases; the air causes some metals to rust, this also is due to the presence of oxygen; methods of protecting iron from rusting; rusting and burning are similar processes, differing only in the rapidity of the chemical action; when metals rust there is an increase of material; about one-fifth of the air is oxygen; only this takes part in rusting and combustion; the products obtained by burning in air and in oxygen are the same. Kindling temperature. Miners' safety lamp. Heat of combustion. Chemical energy. Oxides. Oxides in nature. Respiration. An oxide of carbon. Lime-water test. Ordinary combustion. Lamps. Furnaces. What to do in case of fire. Fire extinguishers. The Bunsen burner. Explosive mixtures. Several of these topics, notably, *What to do in case of fire,* are expanded into full lectures, and are intended to present

practical applications of the principles already studied. Certain portions of the text-book are assigned for first reading before those topics are treated in the laboratory, a second reading and more careful study to be made after the subject is worked over in the laboratory.

The pupil's first laboratory duty is to bend the glass delivery tube and set up the apparatus represented in Fig. 1.[1] This is used, with slight modifications, to generate all gases in the course. The eight-ounce, wide-mouthed bottle, the tin basin, the test tube, the rubber stopper and even the delivery tube being repeatedly used all the year.

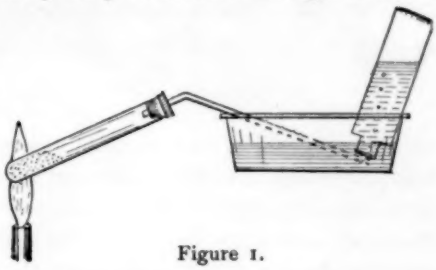

Figure 1.

The manganese dioxide and potassium chlorate already mixed, are distributed upon small pieces of paper. The pupil folds this piece of paper as a physician rolls up a powder, leaving the ends open, and transfers the powder to the bottom of his test tube without clouding the sides of the tube. He is not now instructed in the composition of the powder, because oxygen is enough for him to study at present.

The student soon acquires the ability to hold the apparatus in his hands with ease while generating gases. In this way he is enabled to watch it closely and guard against heating the test tube so as to crack it or melt it, also to guard against melting the rubber stopper or allowing the water to be forced back into the tube. It requires only a few laboratory exercises to make the awkward pupil more or less dexterous.

Hydrogen and Water. — The following is learned from laboratory experiments: Hydrogen and air burn together. Hydrogen may be obtained from water. Oxygen may be obtained from water. Hydrogen and oxygen combine to produce water. Hydrogen and oxygen unite in the ratio of two volumes of hydrogen to one of oxygen. Hydrogen is found in illuminating gas, alcohol, ether, and a candle.

[1] The illustrations of chemical apparatus used in this number of The Record are kindly loaned by Messrs. Henry Holt & Co., publishers of Woodhull and Van Arsdale's *Chemical Experiments*.

For generating hydrogen the same apparatus is used as for generating oxygen (Fig. 2), except that a two-ounce flask is substituted for the test tube to permit of effervescence without driving the acid over into the basin.

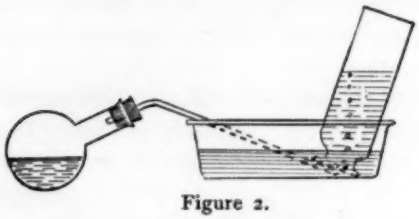

Figure 2.

From recitation and lecture the pupil learns of the prevalence of water in animal, vegetable, and mineral substances; water of crystallization; efflorescent and deliquescent substances; natural waters; impure waters; distillation; water as a solvent; water as an aid to chemical action; water gas; the oxyhydrogen flame and lime light; hydrogen dioxide, an unstable compound yielding oxygen in the nascent state.

The experiment of exploding a mixture of hydrogen and oxygen in the eudiometer is performed in the lecture room as follows: A graduated tube about 35 centimeters long is filled with water and inverted in a glass cylinder full of water which is about 30 centimeters long and 10 centimeters wide. About 12 centimeters of oxygen are passed in through a short delivery tube directly from the test-tube generator and allowed to cool until no further contraction takes place; then its volume is read, the eudiometer being raised until the level of the water inside and outside coincides. In the same manner about 12 centimeters of hydrogen are passed in through a short delivery tube from the two-ounce flask generator. This is allowed to cool and mix thoroughly and the volume of the mixture is read. A leather cushion, which has been soaked in water to get the air out of it, is placed under the lower end of the tube. The tube is clamped down and the mixture exploded by a spark from a Leyden jar or small Ruhmkorff's coil. The leather cushion is now detached and the water enters to within about 6 centimeters of the top of the tube. The volume of the remaining gas is taken after it has cooled. Then the tube is inverted and this gas is shown to be oxygen by passing into it a splinter of wood carrying a spark. The glass cylinder filled with water not only obviates the necessity of making corrections for pressure in the observed volumes of gas, but it makes it safe to stand near the apparatus in

case the eudiometer should be shattered by the explosion. No corrections for temperature are required, the water and gases being allowed to reach the temperature of the room. The whole experiment requires not more than twenty minutes, and, by the elimination of corrections for pressure and temperature, is brought within the capacity of a first year high-school class.

Another experiment which is performed in the lecture room is that of passing steam over hot iron powder. For this purpose the apparatus represented by Fig. 3 is used. The basin rests upon a support and the eight-ounce bottle is clamped in place. The rubber stoppers are pressed into the test tube and two-ounce flask firmly enough to support them. The hands are left free to control the two lamps. The water is kept boiling gently in the flask and the flame is moved slowly underneath the test tube so as to keep the iron powder as hot as possible without melting the test tube. The bottle is filled with hydrogen in a very few minutes. Then the delivery tube is lifted from the water in the basin before any water can be pressed back into the apparatus. Care is taken to keep the test tube tipped so that no water shall trickle toward the dry-hot end.

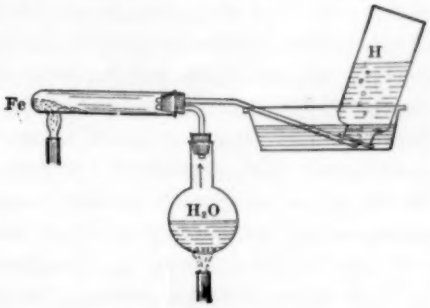

Figure 3.

The apparatus represented by Fig. 4 is used for producing water by passing hydrogen over hot copper oxide.

Figure 4.

The hydrogen generator is allowed to work for some minutes before the flame is applied to the test tube, to drive air out of the apparatus so as to avoid an explosion and to show that moisture does not collect upon the walls of the test tube until the copper oxide is heated.

The whole number of experiments performed in laboratory and lecture room is 8, as follows: 1. To generate hydrogen and show that it burns with air. 2. To obtain hydrogen from water

by means of sodium. 3. To obtain hydrogen from water by means of iron. 4. To obtain hydrogen and oxygen from water by means of an electric current. Proportion by volume, 2 to 1. 5. To show that hydrogen and oxygen when burned together form water. 6. To produce water by reducing copper oxide with hydrogen. In the discussion it is shown how the proportion by weight of hydrogen and oxygen in water might be determined from this experiment by weighing the copper oxide before and after the experiment and weighing the water produced. Thus, if the copper oxide weighed 2.38 grams before and 2.14 grams after the experiment, and if the water produced weighed .27 gram it is obvious that .24 gram of oxygen has been united with .03 gram of hydrogen to form .27 gram of water, and that 8 grams of oxygen would unite with 1 gram of hydrogen to form 9 grams of water. So far as possible such results throughout the course are made more real by being reported from the work of the teacher in his own private laboratory. 7. To cause hydrogen and oxygen to unite in the eudiometer proving the proportions by volume to be 2 to 1. 8. To burn a jet of oxygen in a bottle of hydrogen.

The following questions are typical of those given about once in two months to test the progress of the class:

Describe experiments which may be used to prove: (1) That water is composed of hydrogen and oxygen. (2) That it contains no other elements. (3) That it contains twice as much hydrogen as oxygen by volume. (4) That it contains eight times as much oxygen as hydrogen by weight.

Show how the experiments which you have described teach that oxygen is sixteen times as heavy as hydrogen.

A certain gas in burning united with sixty-four grams of oxygen and produced forty-four grams of carbonic oxide and thirty-six grams of water; of what two elements was the gas composed, and in what ratio by weight were they united in the original compound?

Why should there be a flame when sodium or potassium is put with water, and what is the product of this combustion?

Describe an experiment where an oxidizing agent and a reducing agent were used.

Suppose chemical attraction should cease, would any of the experiments you have performed be possible? Why?

How might you prove that air contains oxygen?

A test tube 6 inches long filled with air is inverted over water. A piece of phosphorus is allowed to rust in this enclosed air for several days, and at the end of that time it is found that the water has risen 1.2 inch; what per cent of the air has been used up in the rusting of the phosphorus? If we direct a flame toward the test tube until the phosphorus melts, will it burn? Why?

Why is there frequently a sudden burst of flame on a coal fire when the upper furnace door is open?

When carbon burns it unites with oxygen in the ratio of 12 to 32. If coal were 90 per cent carbon, how much carbonic oxide would be produced by the burning of a ton of coal? Some ocean steamers burn as much as 500 tons of coal in a day. What weight of carbonic oxide is thus produced? What volume? One pound of the gas will fill about eight cubic feet of space.

Name several observations common to every-day experiences that lead to the conclusion that air is necessary for burning.

When a flame is seen burning at the top of a foundry chimney, is it probably burning all the way down? If not, how may the flame have started? Give reasons for your answer.

Weight of tin taken 1.6 gram and the weight of tin oxide produced 1.8 gram. What per cent of tin oxide is tin and what per cent is oxygen?

12.25 grams of potassium chlorate will yield 4.8 grams of oxygen. An eight-ounce bottle of oxygen weighs about .35 gram, how much potassium chlorate will be required to fill the bottle with oxygen?

Composition of water is $\frac{H}{O} = \frac{2}{1}$, (vol.) and $= \frac{11}{88}$ (wt.); how much heavier is oxygen than hydrogen? If a liter of hydrogen weighs .089 gram, how much does a liter of oxygen weigh?

A liter of water weighs 1000 grams. How many liters of hydrogen and of oxygen will be produced by the decomposition of a liter of water?

What ratio of hydrogen to air would make the best explosive mixture?

Chlorine and the Chlorine Family.—For generating chlorine the same apparatus is used as for generating hydrogen, represented in Fig. 2. In the flask is put a mixture of sodium chloride and manganese dioxide and a little sulphuric acid is

poured upon it. The chlorine gas is caught by passing it up into an inverted bottle of water. This is the most satisfactory way to catch chlorine. No trouble is experienced with the water rushing back into the flask, if a little more manganese dioxide than sodium chloride by volume is taken, if they are thoroughly mixed, and if the mixture is heated very gently. The pupils are taught to manipulate their experiments so that chlorine shall not escape into the air of the room. This is made possible without the use of the hood by catching it over water. All the experiments with chlorine are more successful if the gas is caught over water and well washed, than if caught by displacement of air. To wash any gas we close the hand over the mouth of the bottle, entrap some water along with the gas, and shake vigorously, throwing the spray through the gas, as the rain washes the atmosphere. This is the simplest and most effective way of washing a gas. Powdered antimony is sprinkled into chlorine, making a magnificent shower of sparks, and strips of colored calico and litmus paper are bleached in chlorine to show its marked chemical activity. Sodium is burned in chlorine to show its marked affinity for metals and to illustrate the existence of the chlorides in nature. The chemical activity of chlorine is exhibited by its power to bleach and disinfect and the reason for its not being free in nature is discussed. Chlorine is burned in hydrogen to give a broader view of combustion as a chemical process. Hydrochloric acid is made in the apparatus represented in Fig. 5. Sulphuric acid is put upon sodium chloride in the flask. Hydrochloric acid is passed over and absorbed in water in the test tube, which is kept cool by the bottle of water. The delivery tube extends nearly to the surface of the water in the test tube, but does not quite reach it. In a few minutes the water in the test tube becomes well charged with hydrogen chloride gas. Half of this hydrochloric acid is poured into a second test tube and zinc dropped into one tube to prove the presence of hydrogen, while manganese dioxide is added to the other tube to prove the presence of chlorine.

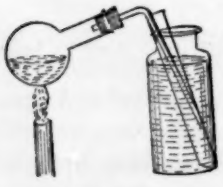

Figure 5.

Hydrobromic, hydriodic, and hydrofluoric acids are made by putting sulphuric acid upon the corresponding salts. The in-

stability of hydrobromic and hydriodic acids is noted. The effect of adding the oxidizing agent, manganese dioxide, in the case of hydrobromic acid is tried. Glass is etched by means of hydrofluoric acid. This is made a lecture-room experiment. The iodine and starch reaction is tried.

ACIDS, BASES and SALTS are discussed in the lecture and recitation; and in the laboratory, sodium hydroxide solution is treated with hydrochloric acid solution until it becomes neutral to litmus paper. The residue (NaCl) is filtered and evaporated to dryness over a water bath. The specimen is taken home and used. A small portion of it is tested with sulphuric acid to generate HCl, and another portion is tested with manganese dioxide and sulphuric acid to generate Cl.

Such questions and problems as the following are given:

Give a general formula for an acid; for a base. Indicate the reaction which takes place when they are brought together. What general name is given to the product formed? How would you make KCl? Na_2SO_4? $NaNO_3$?

How much caustic soda (NaOH) would be required to make one ounce of common salt? (NaCl).

Name another method by which salts are produced than by the neutralization of an acid by a base.

Name the sodium salt of hydrochloric acid; the potassium salt of chloric acid; the calcium salt of sulphuric acid.

What is produced in each case when potassium chloride KCl), potassium chlorate ($KClO_3$), and sodium nitrate ($NaNO_3$) are treated with H_2SO_4?

Compare Cl, Br, and I, stating the points of resemblance and difference from both the physical and chemical standpoints.

How would you distinguish by experiment between the chloride and bromide of sodium?

In general, how would you make any acid? How would you make hydrochloric acid? hydrobromic acid? nitric acid? carbonic acid? hydrosulphuric acid?

How much sulphuric acid and salt would be required to go with ten grams of manganese dioxide?

How much manganese chloride would be produced?

How many grams of chlorine would be produced?

How many liters of chlorine would be produced?

About how many eight-ounce bottlefuls?

SULPHUR.—The physical and chemical properties of sulphur at different temperatures are noted and its crystallization from a state of fusion and from solution; its low kindling temperature; its slight heat of combustion; its affinity for metals. Iron sulphide is made by mixing powdered sulphur and powdered iron and starting the chemical action by touching the mixture with a hot glass rod. A test tube is half filled with the above mixture and the experiment is repeated to illustrate combustion without oxygen. Hydrogen sulphide is made by treating a sulphide with sulphuric acid. This is compared with the way hydrogen chloride, hydrogen bromide, and hydrogen iodide were made. The instability of hydrosulphuric acid and its consequent usefulness as a reagent. Nascent sulphur. Test for the presence of hydrogen sulphide in eggs, coal gas from a coal fire, sulphur-spring water, etc. Products of the combustion of hydrogen sulphide with air or oxygen. Action of vulcanized rubber upon a silver coin. Making sulphides of metals by action of hydrogen sulphide on soluble salts of metals. Testing unknown solutions. Qualitative analysis. Making sulphuric acid from sulphur dioxide by the aid of an oxidizing agent. Making sulphur dioxide from sulphuric acid by the aid of a reducing agent. The use of sulphuric acid in making acids from salts. Importance of sulphuric acid in manufactures. Sulphur dioxide as a reagent. Its bleaching properties. For collecting hydrogen sulphide gas and sulphur dioxide gas we use the same apparatus as for generating hydrogen, illustrated by Fig. 2.

NITROGEN.—The instability of compounds of nitrogen. The action of sulphuric acid upon a nitrate. The action of metals upon nitric acid. Nitric oxide as a reducing agent. Nitrous oxide and nitrogen peroxide as oxidizing agents. Ammonia. Explosives. Nitrogen in foods for animals and plants. Oxidation and reduction products of the decomposition of substances which contain nitrogen. Destructive distillation. The analysis and synthesis of nitrogen compounds. Testing unknown substances for the presence of nitrates, chlorides, and ammonium compounds.

For the preparation of nitric acid, ammonia, and nitrous oxide, the apparatus represented in Fig. 5 is used. For the preparation of nitric oxide we use the apparatus represented in Fig. 2.

CARBON.—Experiments in the destructive distillation of wood, sugar, wax, and soft coal, are performed with the apparatus illustrated by Fig. 6. The solid products are left behind in the test tube. The liquid products are collected in the smaller bottle and the gaseous products gather in the eight-ounce wide-mouth bottle. The solid products which appear to be charcoal are afterward heated in an open tube and shown to yield carbon dioxide by the lime water test. They are then reduced to an ash by the complete combustion of the carbon. The liquid and gaseous products form the subject of a lecture or two with numerous experiments.

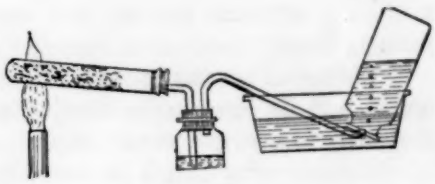

Figure 6.

The instability of organic things; their use as fuels and foods; their liability to decay; the charring of organic substances. The affinity of carbon for oxygen at ordinary and at high temperatures; products of the union. Presence of hydrogen in organic things shown by the formation of water in combustion. Presence of carbon in organic things shown by the formation of CO_2 in combustion. Relation of kindling temperature of hydrogen and carbon; smoky flames; lamp black. Manufacture of illuminating gas; coke. Coal, petroleum, natural gas. Diamond. Graphite. Carbon as a reducing agent. Lead is obtained from litharge by putting litharge upon a block of wood and directing the flame of the Bunsen burner downward and upon it until globules of the lead are separated out. This experiment is used to illustrate the extraction of metals from their ores by the smelting furnace. Charcoal filters. Oxidation and reduction products as illustrated in combustion, decay, the life processes of animals and plants, and destructive distillation from a retort or in the earth. Carbon monoxide in coal fires; in water gas. Marsh gas. Ammonia from compost heaps. Marsh gas in coal mines; fire-damp and choke-damp. Carbon dioxide in respiration; respiration of animals and plants. Use of hemoglobin and chlorophyl. Ventilation. Reason why carbon dioxide will neither burn nor support combustion. Study of flames. Heat and chemical energy

of the combustion of carbon; application of this energy in doing mechanical work. Fermentation by yeast. Soaps.

In the laboratory carbon dioxide is made by the action of an acid on a carbonate and the lime water test, and the flame of a burning taper.

We collect several bottles of air given off by the lungs in one breath and by lowering a burning taper into each bottle show that there is a larger portion of CO_2 in the last than in the first.

We show that CO_2 is produced by the action of the two parts of a baking powder on each other (sodium bicarbonate and cream of tartar).

We heat calcium carbonate to drive off CO_2 and obtain quicklime and slake the lime to obtain lime water; filtering the lime water and pouring some into a bottle of CO_2, shaking and adding lime water till the liquid remains turbid; filtering the hard water thus produced.

We make "hard water" also by dissolving a little chalk in "soda water," and boil some of the hard water to make it "soft."

We try the action of soap on the hard water produced in both of the previous experiments.

We show how mortar, plaster, whitewash, etc., become limestone by putting slaked lime into a bottle of carbon dioxide and tying a piece of sheet rubber air-tight over the mouth of the bottle, and noting the evidence that the CO_2 is being absorbed into the slaked lime.

To show that carbon dioxide and alcohol are obtained by the process of fermentation, we put yeast with a solution of molasses and water in an eight-ounce wide-mouth bottle and invert it in a tin basin and set it in a warm place. In a few hours the bottle is filled with CO_2, as may be shown by lime water or the burning taper. The solution of water, molasses and yeast which has passed out of the bottle and into the basin is now returned to the bottle and set away for further fermentation. In a few days it smells strongly of alcohol and a portion of it is put into the flask of the distilling apparatus represented in Fig. 5, and alcohol is separated out and shown to support a flame. The rest of the solution of water, molasses and yeast, is allowed to ferment further for many days until it makes good vinegar. This is filtered and put into a specimen bottle and labeled and kept to show to next year's class.

Yeast is examined under the microscope.

We also try the power of boiled and filtered yeast to cause fermentation. We make soaps by boiling fatty acids with alkalis.

We obtain potassium carbonate from wood ashes, and we obtain CO_2 by putting an acid upon wood ashes.

PHOSPHORUS AND ARSENIC.—Characteristics of phosphorus and arsenic. Affinity of phosphorus for iodine; for oxygen; use in making matches. The safety match. Allotropism as illustrated by phosphorus, carbon, sulphur and oxygen. Phosphoric acid and its salts. Properties of arsenic oxide; Marsh's test for arsenic. The nascent state as illustrated by the action of chlorine from aqua regia, sulphur from hydrogen sulphide, hydrogen in Marsh's test, the action of oxidizing and reducing agents. Products of the complete combustion of hydrogen arsenide, carbon bisulphide, hydrogen sulphide and a hydrocarbon like kerosene. Products of the incomplete combustion of the same when cool objects are brought into the flames. The affinity of oxygen for these elements in the free state compared with its affinity for them in the combined state.

IMPORTANT METALS AND THEIR ORDINARY COMPOUNDS.—A brief study of the preparation and of the properties of the following metals and a few of their ordinary compounds: potassium, sodium, (ammonium) and calcium; zinc, copper, mercury and silver; aluminium and iron; lead and tin; platinum and gold.

Special attention is given to those compounds which are of great importance in the laboratory, in the industries or in daily life; such as potassium chlorate, potassium carbonate, caustic potash, saltpeter, common salt, soda, borax, lime, mortar, gunpowder, glass, steel, porcelain, the common alloys, etc.

SYLLABUS OF THE COURSE IN PHYSICS

TIME.—Second year of the high-school course. Pupils about fifteen years of age. One year of thirty-two weeks. Two exercises of forty minutes each and two exercises of eighty-five minutes each, weekly, with two hours of home study, making about six hours each week. One period of forty minutes is devoted to a lecture when all the divisions of the class meet together in the large lecture room. The two periods of eighty-five minutes each are given to laboratory work and the remaining period of forty minutes is devoted to recitation. Sometimes one-half of one of the laboratory periods is used for extra lecture or recitation as the subject may demand.

THE PHYSICAL LABORATORY.—The physical laboratory is a large, well-lighted and well-ventilated room. On one side between it and the chemical laboratory is a stock room and an office opening into each laboratory; on another side are a dark room and a tool room. The tables are ordinary library tables, oak, and well polished, 2 feet 3 inches wide by 4 feet 6 inches long. Each table accommodates two workers. Although more than eight hundred students during the past eight years have performed their laboratory work upon these tables, and they have never been redressed, they still look quite as well as the tables that have been used for library purposes. The tables are arranged horseshoe fashion and are twelve in number. In the centre of the horseshoe are other tables which accommodate exhibition apparatus. At the opening of the horseshoe is a table for the teacher's apparatus. At one end of the room is a blackboard, a teacher's desk with twenty-four chairs grouped about it for recitation or supplementary lecture purposes. There is a sink at each end of the room and a working shelf running along two sides of the room underneath the windows. This shelf is supplied with electric current and with gas outlets for Bunsen burners. The apparatus is kept in the stock room and in cases around the sides of the room. Shelves are also provided for books.

THE LECTURE ROOM.—The lecture room is provided with 206 Yale-tablet chairs, an electric-light stereopticon, cases for exhibition and a lecture table well supplied with conveniences for chemical and physical lectures: a hood, a sink, a blackboard, a chart frame, gas, storage battery and dynamo connections; drawers and cupboards well stocked with lecture apparatus. A preparation laboratory opens from this room. There is intercommunication by telephone among the laboratories, lecture room, stock room and other rooms mentioned above.

For text-books we use Henderson and Woodhull's *Elements of Physics* and Woodhull and Van Arsdale's *Laboratory Manual.*

The pupils come to us at about fifteen years of age, desiring most to learn about trolley cars, wireless telegraphy, liquid air, the telephone, etc., and we are not convinced that it is our duty to check these desires and substitute what to them would seem to be dry husks. We therefore teach principles only for the sake of their applications and we very easily find their applications in the things which the pupils are inquiring about. Applications are presented so far as is practicable at the same time with the principles in order that they may give reality to the principles. High-school pupils are not satisfied to be kept "whetting tools" to be used only in college or in after life. What may therefore be considered the crowning features of our work are the excursions described on pages 43-50.

Physics may properly be regarded as a group of several subjects, as Heat, Sound, Light, etc., which, although closely related to one another, are not sufficiently interdependent to determine a natural sequence. This fact is well attested by authors of text-books in the wide variation of orders of topics which they have adopted. The order of topics is not very important so long as a logical and scientific treatment of them is followed. The best order to use in a text-book is not in all cases the best order to use in teaching the subject. It may be well, for purposes of ready reference, that the first division of the subject as presented in the text-book should be definitions of Physical Science, of the Constitution and Properties of Matter, etc.; but these and many other matters will be better understood if interspersed and reiterated throughout the whole course in teaching the subject. Minor considerations may very properly be allowed to determine the order of the chief topics. For example, we put that part

of the subject first which the introductory stages of the laboratory work require; we arrange our course to bring Static Electricity into the coldest and dryest month of the year, so that the experiments may be more successful.

PROPERTIES OF MATTER (*Two Weeks*)

The first lecture deals with: familiar illustrations to develop ideas of the molecular constitution of matter and of molecular force; the solid, liquid and gaseous states of matter and the relation of heat to these, and during the first week exercises are given in the laboratory to determine the ratio between an inch and a centimeter; an inch and a meter; an ounce and a gram; a quart and a liter; a cubic centimeter of water and a gram. In the second week the lecture and laboratory work treat very briefly of such properties of matter as are related to gluing, cementing, welding, soldering, the absorption of air and water by wood, and of oil by leather, the action of lamp wicks and blotting paper, the diffusion of vapors and gases into the atmosphere, the rising of sap in trees, the osmosis of gases and liquids in the human body, crystallization of water, type metal, etc.; the flowing, at ordinary temperature, of rosin, sealing wax, asphalt pavements, ice in glaciers, etc.; watch spring and spring balances, gold leaf, etc.

MECHANICS OF SOLIDS (*Three Weeks*)

The next three lectures present familiar illustrations and applications of the principles of momentum, mass and weight, gravitation and the laws of motion, the pendulum and its uses, uniformly accelerated and uniformly retarded motion, the path of projectiles, the orbits of comets and the planets, the recoil of a gun, the motion of the rotary lawn-sprinkler and simple turbine water wheel; the composition of parallel forces and the application of the principle to levers, pulleys, wheel and axle, balances and machines in general; work and the conservation of energy. The last two merely introduced now, but to be often referred to in future chapters.

The experiments which are used in the laboratory during the first five weeks have a little of the nature of induction, but more of illustration and of verification. Half of them have some-

thing of a quantitative nature, but perhaps not more than a quarter of them are what are usually termed quantitative experiments. They however serve the purpose of making *real* the ideas which we wish to present. They absorb the interests of the pupils, and when performed under the supervision of a good laboratory director and properly related to lecture and recitation work they furnish an abundant fund of information, and we believe they contribute well toward that mental training which we have in view.

MECHANICS OF FLUIDS (*Five Weeks*)

The study of the pressure in fluids is very much simplified by arranging it under three main propositions. It is understood that we refer to static pressure.

LIQUIDS.—The first proposition is (a) *Pressure in liquids is proportional to the depth alone, and is not influenced by the size or shape of the vessels which contain them.* (b) *At any given depth the pressure is equal in all directions.* The first part of this proposition is illustrated by such apparatus as is represented in Fig. 1,[1] and the second part is shown by such apparatus as is represented in Fig. 2. *b c* is in each case the vertical height of the mercury column which is supported by the water pressure at the point *b*.

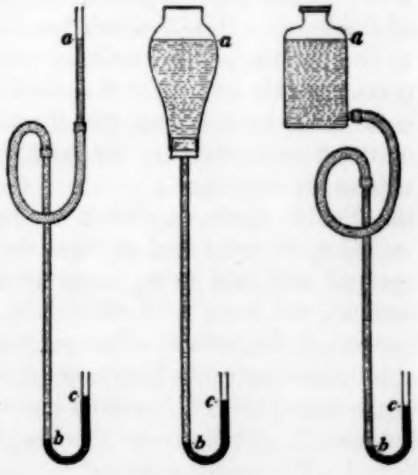

Figure 1.

The burden of the first lecture is to make this seem a naturally and necessary truth and not something paradoxical. Pressure downward, sidewise, and up-

[1] The illustrations of physical apparatus used in this number of THE RECORD are kindly loaned by Messrs. D. Appleton & Co., publishers of Henderson and Woodhull's *Physics*, and Woodhull and Van Arsdale's *Physical Experiments*.

ward, in a liquid is shown to be wholly due to gravity. Buoyancy and specific gravity are treated as merely corollaries of this proposition. For example, let Fig. 3 represent a specimen tube carrying shot and floating in a tumbler of water. If the depth *a b* to which it sinks is 10 centimeters, and if the area of its bottom is equal to 1 square centimeter, the pressure upward upon the bottom of the tube must be 10 grams, and since there is equilibrium, its weight must be 10 grams. It follows that: A floating body must displace its own weight of the liquid. A body that sinks until it is submerged displaces its own volume of the liquid. It will, if left free to move, sink to the bottom of the retaining vessel. It will press upon the bottom of the vessel with a force equal to its own weight, less the buoyant force of the liquid, which is the weight of its own volume of the liquid, which is the weight of the liquid displaced. If a string were attached to it and lifted it from the bottom, leaving it still submerged and this string were attached to a balance we might measure the force with which the object had pressed upon the bottom of the vessel. This subtracted from the weight of the object would give the buoyance, or the weight of the equal volume of the liquid, etc. This matter is discussed as long as it is fruitful, but specific gravity is not dwelt upon longer than one laboratory period. We sacrifice something from this work to find time to measure the water pressure at faucets on different floors of the building, from which we calculate the height of the stories. We measure the pressure in the gas pipes and steam pipes, the pressure which we may exert with our lungs. This is figured in pounds per square inch upon the walls of the mouth and chest, etc. We discuss what is meant by the draught of a ship; how her tonnage may be calculated; how it may be determined what

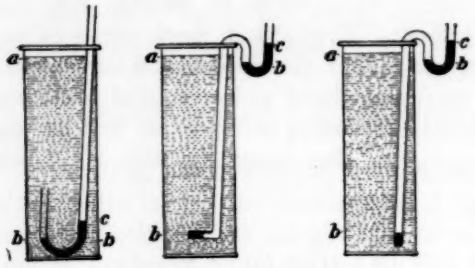

Figure 2.

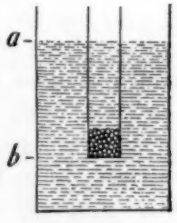

Figure 3.

water she will draw when loaded and when empty; how iron ships float; the use of ballast; why yachts have keels of lead projecting so far down into the water.

For home work, beside the study of the text-book, a number of experiments have been devised. One boy at our suggestion found the volume of his own body as follows: He filled the bath tub with water to the overflow and then carefully got in and submerged himself; he then got out and measured the amount of water which it was necessary to add to again fill the tub to the overflow. This gave his volume. Knowing his weight, he was able to determine his specific gravity which was found to be .89. The question then arose why he could not swim, and it is presumed that the discussion will contribute some additional confidence at the next swimming lesson. The slight difference in weight between fresh water and sea water is noted and the flimsy excuse is removed from those who think they could swim in salt water but cannot in fresh.

GASES. — The second proposition is: (a) *Pressure in gases increases with the depth, but is not proportional to it.* (b) *At any given depth the pressure is equal in all directions.*

The fact that pupils have always lived at the bottom of an ocean of air and have not been conscious of its buoyance, has made them grow up with the feeling that gases as a rule have no weight and cannot exert a pressure. It is therefore necessary not merely to convince them of the fact, but to impress it upon them so that they will feel it to be natural to think of gases as being subject to the attraction of gravity and therefore having weight.

Air is weighed and it is found that one cubic foot of it weighs about an ounce and a quarter. It is therefore calculated that the air in a lecture room whose dimensions are 60x40x20 feet, weighs one and seven-eights of a ton.

Our discussions run about as follows: Contemplate the momentum of countless tons of air moving at a velocity of fifty to a hundred miles an hour. Is it strange that it unroofs buildings, uproots trees, piles high the sand dunes, drifts great snow banks, and raises the sea in huge masses?

The barometer proves the weight of the air and is shown to be only a slight modification of the mercury pressure gauge which we have used for liquid pressures.

The only reason for studying the pressure of gases apart from that of liquids is the fact that gases are compressible while liquids are not, hence proposition two is a review of proposition one with a distinction to be carefully noted. Gases under pressure condense and are like a coiled spring, the outward push of the spring is equal to the pressure upon it, Fig. 4; hence the tension of gases is equal to the pressure upon them. The length of the spring is proportional to the pressure upon it. It is so used in spring balances to determine the magnitude of weights. In the same manner the volume of a gas is proportional to the pressure upon it. This law was the discovery of Robert Boyle in the seventeenth century.

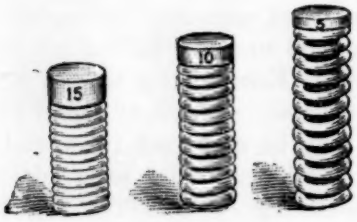

Figure 4.

It must therefore appear that it is gravity which causes a balloon to rise. The balloon floats in the air for the same reason that a block of wood floats on water. We do not say this proves that wood has no weight, but rather it proves that water has weight — hence its buoyancy. The rising balloon likewise testifies to the weight and consequent buoyancy of the air. Air being compressible its density varies with the height; hence we may control the height to which a balloon will rise in the air by throwing out ballast and reducing its weight, or letting out gas and reducing its volume. Not so with the block of wood floating in water. If we weight it until it is submerged, it immediately goes way to the bottom; this proves that the water has uniform density.

Transmission of Pressure through Liquids and Gases. — The third proposition is: *Pressure exerted upon a fluid (liquid or gas) inclosed in a vessel is transmitted equally in all directions, the total pressure upon the walls of the vessel being proportional to the area.* This principle has in a measure been assumed in the study of the two foregoing propositions, which is bad logic, but not necessarily bad pedagogy.

The two pieces of apparatus used for illustrating this principle are represented in Figs. 5 and 6. Mercury is put into the bent tubes (Fig. 5), to serve as a gauge of the pressure. The

mouth of the experimenter is applied to the free end of the tube above at the left; by pinching the rubber tube connection between the first and second pressure gauges, the pressure which he may exert from his lungs is all directed upon the mercury in the first tube. Suppose he finds that this is sufficient to support a column of mercury three inches high, a pressure which he has learned to designate as one and a half pounds per square inch. If now he releases the rubber tube between the first and second gauges and pinches that between the second and third gauges he finds that with an effort equal to that used before he may make each of them register three inches, or one and a half pound pressure per square inch. In the same manner he may exert pressure upon three or any number of pressure gauges simultaneously and find that it is as easy to hold up a hundred columns of mercury as it is to hold up one.

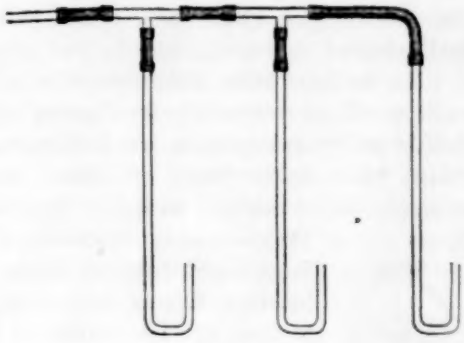

Figure 5.

Figure 6.

The apparatus represented in Fig. 6 is a jelly-cake tin with a rubber cloth tied over the top and a tube inserted into the side. The area of the top is about 80 square inches. A board is laid upon it and weights put upon the board; when the mouth is applied to the tube one has the novel experience of finding that he can lift about 118 pounds by his breath. The hydrostatic press is discussed and it is shown to conform to the laws of machines and thus again the principles of work and the conservation of energy are illustrated.

Having spent about three weeks in the study of the pressure of fluids, arranged under these three propositions, the next two weeks are given to the applications of these principles to siphons, pumps, Cartesian divers, Magdeburg hemispheres, hydraulic elevators, pneumatic cash systems and mailing tubes, door checks,

compressed air motors, air brakes, diving bells, caissons, the ear drum, the physics of respiration, the student's lamp, the fountain ink well and sponge cup, " fountain in vacuo ", Hero's fountain, the specific gravity of milk, cream, whole milk, skimmed milk, and watered milk, etc., etc.

In the laboratory work connected with the pressure in fluids each pupil performs twenty-five or thirty experiments, fully half of which are quantitative, and most of the qualitative experiments have mathematical problems connected with them; for example, in connection with the apparatus illustrated in Fig. 7 the following calculations are called for. In a large wide-mouthed bottle of water a small vial is inserted, having just enough air in the upper part to float it. The weight of the vial is 3.5 grams, the air which it contains is 2.5 cubic centimeters. What must be the volume of glass in it, and what is its specific gravity? The rubber cloth is air-tight over the mouth of the large bottle. If now we exert a pressure of 5 pounds per square inch upon the rubber, what will the volume of the air in the vial become? Will it sink? If so, with how much force will it press upon the bottom of the large bottle? If now we remove the pressure from the rubber cloth, and pull upward upon it with a force of 5 pounds per square inch, what will the volume of the air in the vial become? Will the vial rise above the surface of the water in the large bottle? If so, what volume will emerge?

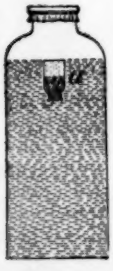

Figure 7.

HEAT (*Five Weeks*)

How Heat is Produced:

Heat produced by friction. Machinery warms up while running. Oil is used to reduce friction and thereby diminish heat. Machines when mismanaged often get so hot in their bearings as to set fire to the oil used to lubricate them. A good example of this is the " hot box " on the car axle. The friction match is heated to the kindling temperature by scratching it upon a rough surface.

Heat produced by pressure. Substances which contract under pressure yield heat. Hence the heating of the sun and

other heavenly bodies under the weight of their own mass. When the pressure is removed and the mass expands it becomes cold. The manufacture of ice, liquid air, etc.

Heat produced by chemical action. Combustion, the slaking of lime, zinc and sulphuric acid all illustrate this. Compost heaps get very warm by reason of the chemical action that is going on in them. Piles of green grass, new grain, new hay, new flour, cotton with seed in it, and oily cotton waste, all produce heat for the same reason. Animal heat.

Heat from electricity. Resistance to the electric current produces heat. This is sufficient to cook with in the electric stove. Our electric cars are warmed in winter by turning electric energy into heat.

SOME EFFECTS OF HEAT:

Expansion of solids. Setting wagon tires, riveting boiler plates, dial thermometers, iron bridges, lamp chimneys, chemical glassware, thermostatic valves and regulators are taken as illustrations.

Expansion of liquids. Mercury thermometers. The action of water, and such metals as crystallize.

Expansion of gases. Law of Charles. Air thermometer. Heat determines the state of a substance. Fusion. Vaporization. Dew point. Humidity. Relation of pressure to evaporation.

HOW HEAT IS TRANSFERRED:

Conduction. The metals. The use of sawdust in ice houses. The use of double windows on dwelling houses. Clothing. Norwegian cooking box. Brick wall around a furnace. Covering of steam pipes. We are living on a globe with only a thin non-conducting shell between us and the intensely heated interior. Water pipes laid a few feet under ground do not loose their heat sufficiently to freeze. Snow protects vegetables.

Convection. The hot-air furnace. The hot-water heater. Winds. Land and sea breezes. Ocean curents. Ventilation.

Radiation. How we get heat from an open fireplace. Would we be able to receive heat from the fire if there were no atmosphere or matter of any kind in which conduction and convection

could occur? How we get heat from the sun. The hotbed. The green house. Compare the effect of our atmosphere to that of a hotbed. Action of moisture in the air. Upper and lower regions of the air. Conditions upon the moon where no atmosphere exists. Why dew and frost collect more upon some things than upon others. How snow produces hotbed conditions. The ether. Wave motions. Kinds of radiation. Velocity of radiation. Absorption, radiation and reflection. Relation of heat and light. The radiometer.

CALORIMETRY AND SPECIFIC HEAT:

Distinction between temperature and quantity of heat. Compare *pressure* and *quantity* in hydraulics, heat, and electricity. Specific heat. Effects of large bodies of water upon climate. The efficiency of hot water heating apparatus. The hot water tank in the kitchen. Land and sea breezes as related to specific heat.

In the laboratory each pupil has three bright metal cups, two of which contain each 200 grams of water at the temperature of the room, and the third contains 200 grams of water and a piece of lead weighing 200 grams with a thread attached. This third vessel is heated, temperature of contents of all three taken, then the 200 grams of hot lead is transferred to one of the vessels containing 200 grams of cold water and the 200 grams of hot water is poured into the other vessel containing 200 grams of cold water. The resulting temperature is found and sources of error discussed. Some of the pupils who have extra time are set the task of determining the amount of heat lost to the cups.

LATENT HEAT:

Heat disappears when solids liquefy. The temperature of water and of common salt, before and after mixing.

The temperature of shaved ice and common salt, before and after mixing. Ice liquefies faster when mixed with salt than otherwise. Why salt is put upon icy pavements. Freezing mixtures. Why ice and snow are so slow to melt.

Heat disappears when liquids vaporize. Take the temperature of ether in a bottle. Expose it to evaporate in a shallow

dish and take its temperature again. Put a drop of water into it and fan the ether to hasten evaporation. Note that the water freezes.

Ice machines which use ammonia. The water bath. The double boiler. Animal heat reduced by perspiration. Sprinkling with water for the purpose of cooling. "Muggy days." Humidity. Why is it difficult to cook on a mountain top? Freezing produced by reducing the pressure. Making liquid air. Why liquid air is so slow to pass into a gas. The temperature of compressed air motors. Freezing "quicksands" for engineering purposes. The regulation of animal heat.

Heat reappears when vapors liquefy. Steam heating of buildings. Moderation of temperature during rain. Moist air accompanying Gulf Stream.

Heat reappears when liquids solidify. Fuse sodium sulphate crystals. Allow the liquid to cool quietly. Insert a thermometer and note the rise in temperature as the crystals form again. Temperature in centre of a snow storm. Tubs of water put in a cellar to keep vegetables from freezing. Large bodies of water in freezing modify the climate.

In the laboratory each pupil performs about forty experiments, one-quarter of which are quantitative; the others are chiefly qualitative, many of which are intended to parallel larger phenomenon in nature and all of them have for their main purpose the making real of the ideas presented.

MAGNETISM AND ELECTRICITY (*Eight Weeks*)

MAGNETISM:

Lodestone. The making of magnets. Magnetic substances. Lines of force about a magnet. Each molecule a magnet. The earth a magnet. Charts of the lines of force upon the earth. Mariner's compass. Law of inverse squares.

Each pupil performs in the laboratory about eight or ten experiments in magnetism, such as the following:

The apparatus represented in Fig. 8 consists of a glass tube fitted into a cork, containing pieces of soft iron wire, each about one-quarter of an inch long. Find how many bits of iron each pole of a bar magnet will lift and try the power of the magnet

at various points between the poles. Lay a second bar magnet upon the first with like poles together and repeat the experiment. Repeat the experiment, having unlike poles together. Place one pole of a magnet upon the upper end of the glass tube and place the opposite pole of another magnet against the side of the tube an inch or two below the upper end. Try, now, the power of the upper magnet to lift bits of iron. Reverse the poles of the lower magnet and try again.

Figure 8.

STATIC ELECTRICITY:

Charges of electricity, how developed, how maintained. Conductors. The influence of electrified bodies upon neighboring objects. Electrophorus. Leyden jar. Distribution of charge. Lightning. Gas-lighting by static machine.

Each pupil performs in the laboratory about ten or twelve experiments in static electricity, such as the following:

Bring an electrified stick of sealing wax underneath a pith ball, *e* (Fig. 9), suspended by a copper wire. Make the sealing wax approach very near to the pith ball, but do not allow it to touch. While holding the sealing wax near to *e*, lift the pith ball, *f*, which is also suspended by a copper wire, off from the copper wire, *b c*, and hang it upon the silk thread, *c d*. A loose piece of silk thread, *g*, is provided, so that this may be done without touching the copper with the fingers. Test now each ball with both glass and sealing wax to determine whether it is positively or negatively electrified.

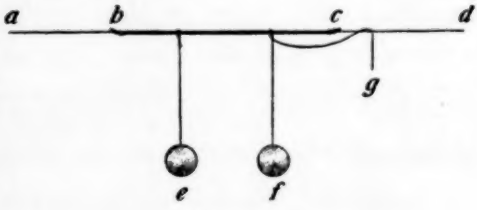

Figure 9.

Hold an electrified stick of sealing wax near to but not touching a pith ball suspended by a silk thread. Touch the pith ball with the finger while it is near the sealing wax. Test now

the pith ball with both glass and sealing wax to determine whether it is positively or negatively electrified.

Can you, by means of an electrified glass tube, charge a pith ball suspended upon a silk thread either positively or negatively at pleasure? Try it.

ELECTRIC CURRENTS:

Sources of electric currents. Electric potential. Relation of static electricity and electric currents. Typical cells. Chemical, heating, and magnetic effects of electric currents. The uses of electromagnets in telegraph sounders, in electric bells, in electric motors, etc. The galvanometer. The ammeter. The voltmeter. Ohms. Volts. Amperes. Electrical measurements. Induction. The telephone. The magneto-electric machine used for telephone calls. The dynamo. Transformers. Thermo-electric generators. The thermopile.

Each student performs in the laboratory about twenty-five or thirty experiments in electric currents of which the following are typical: Examine an electric bell and trace the path of the current through it. Send the current through it so as to make a "single-stroke" bell; a "clatter" bell. Illustrate by diagrams. Connect your battery with a voltmeter and ammeter in parallel. Add slowly from 0 to 10 ohms resistance to the ammeter circuit. Record the readings of voltmeter and ammeter at each step. Find about what current is required to operate the pieces of apparatus furnished you. (Electric bell, small motor, electrolysis apparatus, etc.) Connect two motors with a rubber band. Operate one with a battery and connect the other with the galvanometer. Is the second motor producing a current as a dynamo? If so, how much and what is its electromotive force? Operate the hand dynamo and see whether it goes harder when its current is made to do work, such as decomposing water, heating a wire, ringing a bell, operating a motor, etc.

LIGHT (*Five Weeks*)

The nature of light. Its velocity. Its sources. Law of inverse squares. Relation between temperature and intensity of light. Visual angle; how it helps us to estimate distances.

Shadows. Eclipses Light through small apertures. Laws of reflection. Images in plain mirrors. Concave mirrors. Enlarged images formed in concave mirrors. Inverted images in concave mirrors. Diminished images in convex mirrors. Curved image from a straight object. How daylight is diffused. Halos about street lights and about the moon. Illumination of clouds at sunset. Moonlight and the phases of the moon. How the dark part of the new moon is made visible. Why transparent objects and good reflectors are themselves invisible. Reading from glazed paper. Twilight. Refraction. Index of refraction. Critical angle. Total reflection. How refraction lengthens the day. Mirage. The brilliancy of precious stones. Refraction of light enables us to see colorless and transparent fluids. Prisms. Lenses. Enlarged images produced by refraction. Inverted images produced by refraction. Focal distances. How a lens forms a picture. Conjugate foci.

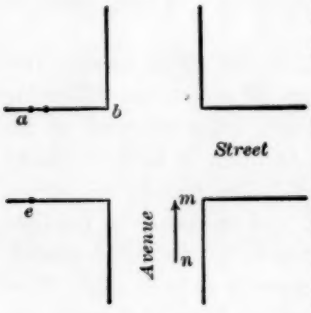

Figure 10.

The simple microscope. Compound microscope. The telescope. The photographic camera. The human eye. Nearsightedness. Farsightedness. The spectrum. The invisible spectrum. Complementary colors. Roentgen rays. Hertz waves. Polarization of light. The identity of the various forms of radiation.

Each pupil performs in the laboratory about twenty exercises in light. Most of them are quantitative. Some of these exercises consist of constructing diagrams to illustrate principles. For example, having developed by means of apparatus the laws of reflection, the pupils are called upon to construct such diagrams as follow:

Suppose you live at *e* (Fig. 10), and across the street at *ab* is a show window which serves as a mirror; *mn* is a street car passing up the avenue. Complete this diagram, showing where the image *mn* will appear to be located, and showing the direction in which the image will appear to be moving. Where must a placard be hung upon the show window to hide the point *n* from your vision.

Suppose $cc'c''$ (Fig. 11) is a curved mirror, the centre of whose

curvature is *d* and that *mn* is an object before the mirror and that *e* is the eye of an observer. Complete the diagram, making it show the position of the image *m'o'p'n'*, its shape and its size; also the angles of incidence and reflection for each of the four rays. Measure these angles with your protractor to determine whether the figure is correct. Test the truth of your conclusion by holding the curved mirror before your face and bringing a small object, *mn*, between your face and the mirror.

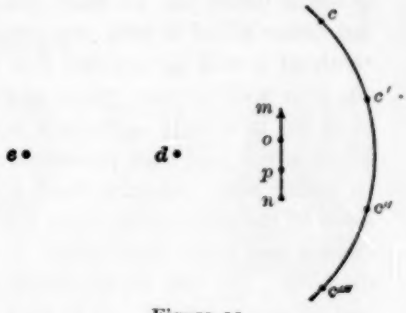

Figure 11.

Let *mn* (Fig. 12) represent a vertical line across your face, *e* the position of your eye, *ab* the mirror, *d* the centre of its curve. Complete the diagram, showing by lines, the courses which rays of light from *m* and *n* must take in order to reach the eye by reflection from the mirror, showing also the position and relative size of the image *m'n'*. Test the angles of incidence and reflection with your protractor.

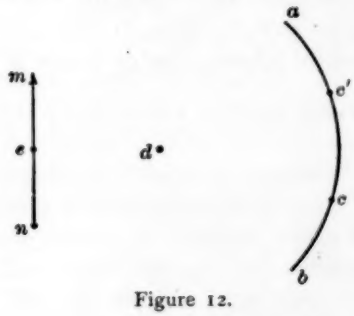

Figure 12.

SOUND (*Three Weeks*)

Sources. Transmission. Loudness. Pitch. Quality. Reflection, echoes. Velocity. Vibration of strings. Sympathetic vibration. Music. The scale. Melody. Chords. Harmony. Counterpoint. The voice. The ear. The phonograph. The telephone.

Each pupil performs in the laboratory about fifteen exercises in sound, most of which are qualitative.

It will occur to those who read over this syllabus of work in physics that there is too much of it to be done satisfactorily. We find this to be true. The amount which we actually accomplish differs considerably from year to year. The ground of the foregoing syllabus has all been gone over in our high-school classes, but never all of it with any one class. Probably as much as one-tenth of it will be omitted this present year, and a good deal of the rest will be very much slighted. But we find our tendency is to get in a little more each year by connecting the parts better. Ideas which had been presented in an isolated fashion are brought in under some common head and by serving as further illustrations of the same thing serve not to increase the labor, but to make clearer and easier that which would have been rather obscure and difficult. By this means alone we have come to teach the subject of pressure in fluids in half the time which we once required, and at the same time we treat it more completely than formerly.

Incidentally we are bringing in more of the history of chemistry and physics each year and more of the biography of the masters. The pupils are buying for their own libraries more books related to the subject of chemistry and physics each year and the number of them who have private laboratories at home is increasing each year.

EXCURSIONS

An essential feature of our work in physics and chemistry is the pursuit of these subjects outside of the lecture, the recitation and the laboratory into the daily life. For this purpose we attempt so far as practicable excursions. In New York City, high-school pupils have so many home engagements that it is not possible to get a large portion of any class to go on excursions out of school hours, and it is not possible to take them away from the building on excursions during the school hours, because of their engagements with the other teachers. We do however arrange a few excursions within the city limits for such as can go to gas factory; sulphuric acid factory; soap factory; mineral water factory; candy factory; glass, china, pottery, lime, mortar and cement works; ice factory; water works; boiler works; machine shops, power houses, etc. From such excursions taken by comparatively small groups, reports are given to the whole class. But fortunately we have within our own buildings a plant which furnishes admirable opportunity for studying physics and chemistry in a very practical way. This we can visit during the regular laboratory periods, using the lecture and recitation periods for discussion and for demonstration with models and charts. The following outline will serve to indicate the nature of this work. Classes from the elementary school are also taken upon excursions about the buildings, and lessons suited to their needs are selected from the following outline:

Facts Brought Out by Excursions about the Building

Cost of plant for heating, lighting and ventilating Teachers College, about $100,000, and for Horace Mann School about $45,000 in addition.

Where our coal comes from. Its formation. How transported.

Hard and soft coal. Chemical constitution.

Our coal vaults hold about 240 tons — one boat load.

Consumption approximately as follows:

September	50	tons
October	150	"
November	200	"
December	250	"
January	300	"
February	300	"
March	250	"
April	200	"
May	150	"
June	50	"
	1900	"

Approximate cost, $6,500.

What constitutes good coal. Use and relative cost of various sizes.

What constitutes good firing. Chemistry and physics of the process.

Possible temperature of the fire.

Duties of fireman.

Duties of coal passer.

Proportion of *ash* in coal.

Proportion of *ashes* in coal.

Why the distinction is made.

Ash cars and elevator. Reason for such an equipment.

Capacity of ash elevator 2,000 lbs.

Capacity of car 600 or 700 lbs. About three ash-car loads fill a street ash cart.

Dumping the ash cars. The ash chute.

What the street cleaning department does with the ashes.

Construction of boilers.

Allowance made for the expansion of grate bars.

Area of grates 27 square feet for one of the 136 horse-power boilers, or 1 square foot of grate for five horse power.

Allowance for expansion and contraction in boiler tubes.

Capacity of boilers:

No. 1	157	horse	power
No. 2	136	"	"
No. 3	136	"	"
No. 4	136	"	"
No. 5	136	"	"
	701	"	"

Square feet of heating surface, 7,700=11 square feet for each horse power.

In process of construction:

No. 6	. . . . .	209	horse power
No. 7	. . . . .	209	" "
No. 8	. . . . .	209	" "
		627	" "

Our five furnaces consume about 1 ton (2,240 lbs.) of coal per hour when doing their best work. It is estimated that under those conditions they generate 700 horse power. Hence 3.21 lbs. coal=one horse power per hour. One horse power= 33,000 foot pounds. 772 foot pounds=one British thermal unit. One B. T. U.=amount of heat necessary to raise 1 lb. of water at maximum density 1° F. One horse power= 42.75 B. T. U. It is estimated that our boilers evaporate 30 lbs. of water for each horse power hour; that is, 1 lb. of coal evaporates about 9 lbs. of water, or more exactly, 9.375 lbs. at the pressure of 90 lbs. per square inch which we maintain. Calculate the number of thermal units required to evaporate that amount of water under the conditions which obtain.

The number of thermal units which may be produced by burning 1 lb. of our coal in our furnaces may be estimated at 14,000.

Suggest ways to account for the loss of heat.

Boiler inspections by Police and Insurance Company.

Insurance (Board of Fire Underwriters).

Method of testing boilers.

Causes of boiler explosions.

Cleaning boilers — Corrosion and incrustation.

Effect upon amount of fuel used and protection of pipes from over-heating.

Filtered water.

Exclusion of cylinder oil.

Amount of water lost from the system each day.

Trace products of combustion to chimney.

Possible products and significance.

Possible temperature of gases in the chimney. Height of chimney 100 feet and diameter 75 inches. Cause of draught.

Automatic damper control.

Water gauge on boilers.

Steam gauge on boilers. Show mechanism. Self-recording gauge in engineer's room.
Pressure maintained at 90 lbs. per square inch.
Boiling temperature of water under that pressure.
One cubic foot of water will expand into about how many cubic feet of steam at the pressure maintained in our mains (90 lbs. at gauge, 105 lbs. absolute.)
Return pumps and drip tanks.
Importance of keeping constant supply of water in boilers.
Method of emptying pits under drip tanks by "blow off siphon."
Trace steam mains to reducing valve.
Non-conducting coverings of steam pipes.
Use of angles in main.
Mechanism of reducing valve.
After passing through the reducing valve the pressure maintained by the pump of our Webster system is 10 lbs. less than the atmospheric pressure=5 lbs. absolute pressure. Under these conditions it will require about how many cubic feet of steam to produce 1 cubic foot of water in the return pipes?
Vacuum gauge.

Low Pressure Steam System:

Indirect Heating System. Total volume of air supplied. Total volume of air in rooms.
Cold-air inlets. Stacks of steam pipes. Inlet fans and engine. Three at Teachers College operated by steam and two at Horace Mann School operated by electricity. Thermometer. What temperature maintained. Supply ducts. Inlet registers with red cords — ducts. Outlet fans and motors — seven in number at Teachers College and two at Horace Mann School — in garret. Cupolas and shutters.
Diagrams of the system in Teachers College and Horace Mann School. Use of anemometer to determine efficiency of ventilation.
Methods of testing purity of air.
Results found in Teachers College and Horace Mann School.
Dryness of air in buildings, cf. desert climate. Humidostat.

Effect of extreme dryness in winter and moisture in summer upon our woodwork and furniture. Method of protecting wood from such effects.

Direct Heating System. Risers. Radiators — form and construction — thermostatic outlet valve. Return pipes — tank-pump-boiler.

Latent heat of steam. Radiation of heat not dependent upon circulation of air. Heat distributed from the steam radiators, both by convection and by radiation.

Small capacity of dry air for heat. Effects of moisture in the air upon its capacity for heat.

Webster system.

Automatic return pumps and automatic pumps for Webster system.

Steam traps.

System of Temperature Regulation:

Thermostats and thermostatic valves. Thermostatic pumps to control both indirect and direct systems.

Methods of heating, without ventilating, building in early morning before pupils arrive and in afternoon when only few are in the offices of the building.

High Pressure Steam System:

Engineer's examinations.

Duties of engineer and assistant.

Steam engines for fans and dynamos — capacity.

Steam pumps — capacity.

Supply steam. Cylinder. Piston and piston rod. Valves for admission and escape of steam in cylinder.

Fly wheel and driving pulley. Governor. Exhaust steam.

Cylinder oils and engine oils.

Characteristics, — amount used, — cost.

Hydraulic Elevators:

Elevator pumps. Pressure tank. Reservoir.

Cylinder, piston, valves, pulleys and cables.

Car, electric call bells, electric lights, gas lights.

WATER SYSTEM:

Croton pressure. Source and cause of variation. Water meters. Amount of water used in buildings. Cost.
Filter. Contents of bed. How kept clean. Capacity 50,000 gal. (=7,000 cu. ft.) a day.
House pump. Tanks in garret.
Electric signal for full and empty tank.
"Tank pressure." Uses of water about the building.
Floating stop cocks. Siphon discharges. Hot and cold water. How heated.
Automatic arrangements. Temperature regulating valves for shower baths in gymnasium.
Waste pipes. Traps. "Back air" pipes.

OIL FILTER.

ILLUMINATING GAS:

Its manufacture.
Gas meter. Amount used in buildings. Cost.

DYNAMOS:

No. 1 55 kilowatt, speed 280 r.p.m. 480 amp. at 115 volts
" 2 150 " " 230 " 1280 " " 115 "
1760
" 3 in process of construction.
" 4 in future.

Direct — connected with engines, multipolar; field, armatures, commutators.
Switch board — automatic cut out — busbars — rheostat.
Capacity of switches — fuses.
Voltmeter — construction.
Ammeter — construction.
Tactometer for determining number of revolutions per minute.
Capacity of various conductors — insulation.

ELECTRIC LIGHTING:

3 arc lights			= 15	amp.
8 arc-light stereopticons			= 80	"
208 incandescent lights,	east wing		= 104	"
437 "	"	south "	= 218½	"
391 "	"	west "	= 195½	"
541 "	"	north "	= 270½	"
866 "	"	Horace Mann school	= 433	"
			1316½	"

ELECTRIC HEATING:

Electric oven . . . . . = 13 amp.

ELECTRIC POWER:

One watt=1 ampere per second at 1 volt.

One horse power=746 watts=about 7 amperes under the average voltage at the various machines in these buildings.

One kilowatt=1000 watts.

Wattmeter.

MOTORS:

1–25 horse power,	repair shop		= 175	amp.
1–10 "	"	machine tool room	= 70	"
1–10 "	"	wood turning room	= 70	"
7– 3 "	"	attic fans	= 150	"
1– ½ "	"	organ motor	= 3½	"
2–22 "	"	basement fans, Horace Mann school	= 300	"
2–11 "	"	attic fans, Horace Mann school	= 150	"
1–28 "	"	elevator, Horace Mann school	= 200	"
			1118½	"

Total amount required to operate entire plant=2448 amperes.

Capacity of generators=1760 amperes.

Electric elevator — mechanism.

CLOCKS:

Self-winding by electric batteries and synchronized hourly by Master clock.

In Teachers College	75
In Horace Mann school	55
	130 clocks.

Mechanism and connections.

TELEPHONES:

Long distance system — private exchange. Switch-board cabinet. Two trunk lines — No. 1222 and 1223 Harlem. Seven stations in Teachers College and three in Horace Mann School — ten stations.

Interior telephone system — switch board — six trunk lines. 65 stations in Teachers College and 10 in Horace Mann School — 75 stations. Perfect intercommunication among stations on four of the trunk-line systems without the interposition of *Central.*

Mechanism of receivers, transmitters, annunciators, etc., etc.

The lecture room and laboratories are well supplied with dissected models of many of the machines. There is also a good supply of charts, diagrams, photographs and lantern slides for illustrating the machinery of our plant.

DEPARTMENTAL NOTES

PHYSICAL EDUCATION

The new building which the recent gift of $250,000 to Teachers College makes possible, will provide facilities for several very important phases of educational work, and the institution will have one of the finest of the buildings devoted to the interests of health. It is remarkable, but quite in keeping with the history of the College, that the need which Dean Russell emphasized in his last report for an adequate equipment for the training of school hygienists and teachers of physical education, should be filled so quickly through the munificence of an anonymous donor. It is a striking evidence of the appreciation of this neglected side of education on the part of some generous friend of the College.

This new building will be unique in several respects. It will provide several gymnastic halls and rooms for games and special forms of exercise, so that a large number of people of different ages and both sexes may be engaged in healthful exercise at one time. These unusual facilities for exercise and play are particularly important where the opportunities for outdoor recreation and exercise are so limited as they are in a great city like New York. The building will provide much needed opportunity for general and special forms of exercise for pupils of the Horace Mann Schools, women students of Teachers College, and instructors of both these institutions. It may also be used by Barnard students and women graduate students of the University. The court behind the building will have a swimming pool, covered by a skylight. The basement will contain bowling alleys and handball courts. On the first floor will be the offices for general medical consultation, the offices of the department, and rooms for physical measurements and examinations. Another room will

provide for the special examination of the eyes. There will also be a study and class room for the special students of the department.

On the second floor there will be three large exercise rooms to be used by the elementary pupils of the Horace Mann School in the morning, and by older students in the afternoon. This floor will also have a class room and offices for one or two instructors. The third floor will be the main dressing room floor, and will have lockers and showers, and separate rooms for students and instructors. Smaller rooms will be equipped for corrective gymnastic work to meet the needs of those who require individual care.

On the fourth floor will be the main gymnasium, a large, airy, light hall, with running gallery, and apparatus of various kinds. One end of this floor will be divided into two stories, and here will be found instructors' offices and rooms for photography, spaces for such exercises as fencing, and one or two rooms for games of different kinds. In various parts of the building there will be rooms which can be used for laboratory purposes. These will provide facilities for the investigation of the effects of different kinds of exercise, and other problems of physical education and school hygiene.

The gymnasium will not be equipped with the apparatus of any particular system of physical training, but the best appliances from various sources will be grouped so as to provide the most favorable conditions for the work which is to be done.

The fact of greater significance, from an educational standpoint, is the remarkable completeness of the material equipment which the College will have for the training of specialists in physical education. There will be lecture rooms, laboratories, exercise halls, and in short, provision for both the theoretical and practical sides of the course of instruction. The student will also have unusual opportunities for observing the different kinds of practical work done in this field.

There is a large demand to-day for teachers and supervisors of physical education and school hygiene who have been broadly and thoroughly trained and who stand in all respects on a par with teachers of other branches. Special teachers in this line have in most cases lacked adequate general education, and have been trained too narrowly, and without sufficient knowledge of

the relation of their own to other subjects, or to education in general. This new building and its equipment, with the extraordinary advantages afforded by the College, the University, and New York City, will provide unequalled facilities for the training of special teachers.

It is proposed to establish a professional course in physical education leading to the Bachelor's diploma, similar in plan and requirements to the professional courses in other departments. An outline of some of the courses planned for this diploma will be found in the new Announcement of the College. With this definite provision of a workshop for the department, it will be possible for students who wish to specialize in physical education to shape their work so as to begin the two years' professional course in October, 1903. T. D. W.

GEOGRAPHY

The College Entrance Requirement in Geography. — A comparison of the Secondary Course of Study in Geography in the Horace Mann School, as outlined in the RECORD, Vol. II, March, 1901, pp. 74-104, with the recently published outline of Requirements in Geography of the College Entrance Examination Board, in Document No. 8, January 10, 1902, pp. 35-40, will show an essential similarity of plan. In fact, the course in the Horace Mann School was outlined to meet the requirements for College Entrance as they had at that time already been advocated by the sub-committee on Geography of the Committee on College Entrance Requirements of the National Educational Association.

The course in the Horace Mann School covers the ground in a somewhat different order of larger topics, but the course can be easily rearranged to meet the needs of teachers.

It will be noted on a comparison of the two publications that certain topics are treated in the Course of Study much more fully than the Examination Board outline would imply as a necessity. Among such topics that may if necessary be abridged for College Entrance preparation are those under the atmosphere — rainfall and climate; under the ocean — the formation of shore lines; under land — map projection, coastal plains, old plains of erosion, embayed mountains, work of underground waters, work of

glaciers. The summary in reference to earth and man can also be largely omitted, the details being introduced as they need to be in the progress of lessons on the physical topics.

The list of possible exercises published by the College Entrance Board, is a valuable adjunct to the Course of Study, inasmuch as it provides a means of valuation for the laboratory exercises published in the Course of Study. Any well trained teacher should find the Course of Study of the Horace Mann School easily applicable to the needs of college entrance requirement, though care should be taken in choosing the topics to be emphasized to select those that will best round out the text used as guide, or for collateral reading.

New Quarters for Department. — The Department is now adequately housed in a series of rooms in the east wing of the second floor of the college building. On the east side are the offices of the head of the Department, and a laboratory with table accommodation for fifty students. This room also has a northern exposure, thus allowing a window shelter for meteorological students. Adjoining this room, and with an exposure to the north and west is a lecture room, with seats for fifty students, and fitted with electric lantern, maps, models, etc., for lecture use. The remaining rooms, with an opening on the central court of the building, are an office for the tutor in the Department, and a large stock and work room for the storage of maps, models, and other geographical appliances. Thus the accommodations are ample for both graduate and undergraduate work.

Professor Dodge, head of the Department of Geography, is Chairman of the Committee of Seven appointed in December, 1901, by the New York State Science Teachers' Association, to prepare a course of study in secondary school geography. The committee made a preliminary report at the meeting of the Association in December, 1901, and presented a tentative course of study that will be printed in full in the report of the Association meeting to be published as a Bulletin by the Regents of the University of the State of New York.

The Committee was continued for one year, to prepare a series of laboratory exercises for secondary school work, and also to prepare a course of study for elementary schools.

The Journal of School Geography, which had been edited for five years by the head of the Department of Geography, was

merged, beginning in January, 1902, with the *Bulletin of the American Bureau of Geography,* which had been issued by Professor Lehnerts, of the State Normal School, Winona, Minn., for two years. The successor to these two periodicals is known as the *Journal of Geography,* and will be edited by Professors Lehnerts and Dodge and Dr. J. Paul Goode, Instructor in Geography in the University of Pennsylvania. The board of editors have as assistants a goodly number of associate editors, chosen from among the scientific geographers and leading geography teachers of the country. The new *Journal,* like its predecessors, will be devoted to the advancement of geographic education.

R. E. D.

BIOLOGY

The outline of the Course in Botany, given in the Horace Mann School, as published in the TEACHERS COLLEGE RECORD, Vol. II, No. 1, agrees very closely to the standard entrance option in botany adopted by the College Entrance Examination Board as far as the topics and amount of work is concerned. The Horace Mann outline, however, embodies in addition the doctrine that there should be given first a synthetic course on the structure and physiology of plants, followed by a study of types.

The treatment of the subject of Ecology, which in the entrance option is outlined separately from the remainder, is planned for in the Horace Mann outline in connection with other topics. This, of course, is what is contemplated by the Entrance Board.

The Department of Biology in Teachers College may now be said to be fairly well equipped. There is, first of all, a sufficient amount of floor space for comfort for the number of students at present in attendance.

There are two laboratories, one of which accommodates very comfortably thirty students at one time, all of whom have a good amount of space and of light in which to work. The same room serves as a lecture room, there being a semi-circle of chairs for the accommodation of thirty students. A steel aquarium rack and a fair-sized conservatory provide for the reception of such animals and plants as are in use for study.

A smaller laboratory can be made to hold twenty-four students engaged in laboratory work.

In addition to the two laboratories there are two stock rooms, one for glass ware, chemicals, and the like, the other for plant and animal materials for class use. A third stock room of good size serving for the storage of materials in large amounts, large aquaria, and wares of various kinds, completes the suite of available space for the magazine.

There is also a very good dark room for photography, and one for physiological experimentation, in which the temperature is fairly constant, and into which no light at all can enter.

Two small offices for the use of the instructors complete the suite of rooms, of which the lighting, an important feature, is excellent, since the exposure is chiefly north and partly east.

The equipment has been increased this year by the purchase of the Leuckart zoölogical and Kny botanical charts, and by the building up of demonstration preparations of the anatomy, morphology, and embryology of animals and plant types.

The following studies are in progress:

Professor Lloyd: On the embryology of the Rubiacæ, viviparity in Podocarpus, and other minor problems.

Dr. Bigelow: On the embryology of Balanus.

F. E. L.

PICTURES FOR NATURE STUDY

By LOUISE CLARK

Student in Teachers College; Principal-elect of the Primary Department and Teacher of Primary Methods in State Normal School, Potsdam, N. Y.

LIST OF ABBREVIATIONS

A.	*Animals from Life*, Rand, McNally & Co., Chicago.
A. M. J.	*American Museum Journal*, American Museum of Natural History, N. Y.
Au.	The Autotype Co., 74 New Oxford St., London.
B.	George P. Brown & Co., Beverly, Mass.
B. 1.	Brown one-cent prints (5½ x 8); 55 for 50 cts., 120 for $1.
Ber.	Berlin Photographic Co., 14 E. 23d St., N. Y.
Braun	Braun, Clement & Co., 249 Fifth Ave., N. Y.
Busse	George Busse, 12 W. 28th St., N. Y.
C.	Copley prints, Curtis and Cameron, Pierce Bldg., Boston.
C. L.	*Country Life in America*, Doubleday, Page & Co., N. Y.
C. Mag.	*Century Magazine*, Century Co., N. Y.
Cosmos	Cosmos Picture Co., [illegible] Broadway, N. Y.
D.	Detroit Photographic Co., Detroit, Mich.
D. of A.	Department of Agriculture, Washington, D. C.
E.	A. W. Elson & Co., Boston.
E. A.	Elson carbon photographs, 30 x 44, $10.
E. B.	Elson, 27½ x 34½, $5.
E. C.	Elson, 20 x 25, $3.
E. D.	Elson, 16 x 20, $1.50.
E. F.	Elson, 13 x 19, $1.50.
E. R.	Elson, 19 x 25, $3.
E. I.	Elson, 28 x 35, $4.
E. II.	Elson cardboard mats, $15.
E. III.	Elson, 21 x 27½, $4.
E. IV.	Elson: Old Masters, 21 x 27½, $2; Modern Masters, 15¾ x 21½, $1.50.
Eth.	Bureau of Ethnology, Smithsonian Institute, Washington, D. C.

E. E. . . . . Etchings and Engravings, Frederick Keppel & Co., 24 Van Buren St., Chicago.
E. Mag. . . . *Everybody's Magazine,* Wanamaker & Co., N. Y.
F. . . . . Foster Brothers, 3 Park Square, Boston.
H. . . . . Harper, Helmer-Taylor and Soderholtz prints, J. R. Lynch, 257 Fifth Ave., N. Y.
H. 1. . . . . Harper, one-cent pictures.
Hanf. . . . . Franz Hanfstaengl, 114 Fifth Ave., N. Y.
Hanf. R. . . . Carbon, or photogravure, 23 x 29, $3.
Hanf. I. . . . Carbon, 29 x 36, $3.
Hanf. F. . . . Carbon and photogravure, 15 x 20, $1.
Hanf. C. . . . Carbon (silver prints), 4 x 5, 30 cts.
I. S. . . . . . *International Studio,* John Lane, Publishers, N. Y.
L. . . . . The London Art Co., 1624 Chestnut St., Philadelphia.
L. M. . . . . *Ledger Monthly,* Philadelphia.
M. . . . . A. W. Mumford, 203 Michigan Ave., Chicago.
M. 2. . . . . Mumford two-cent pictures.
M. Mag. . . . *Metropolitan Magazine,* N. Y.
Mc. . . . . . *McClure's Magazine,* S. S. McClure Co., N. Y.
N. E. . . . . *New England Magazine,* American Co., N. Y. and Boston.
N. S. . . . . *National Sportsman.*
O. . . . . J. F. Olsson & Co., Cambridge, Mass.
Out. . . . . . *Outing Magazine,* Outing Pub. Co., N. Y.
P. . . . . The Perry Picture Co., Malden, Mass., and 76 Fifth Ave., N. Y.
P. 1. . . . . Perry one-cent pictures (5½ x 8); 120 for $1.
P. ½. . . . . Perry one-half cent pictures; for fifty or more.
P. 2. . . . . Perry two-cent pictures, 7 x 9, colored. (No orders for less than 25 cts.)
P. 5. . . . . Perry five-cent pictures, 10 x 12.
Prang . . . . The Prang Educational Co., 3 W. 18th St., N. Y.
P. I. . . . . . *Pratt Institute Monthly,* Pratt Institute, Brooklyn.
P. Rep. . . . . Photo Reproduction Co., Chicago.
R. . . . . F. A. Reinehart, Photographer, 1522 Douglas Ave., Omaha, Neb.
S. . . . . E. Steiger & Co., 25 Park Place, N. Y.
S. I. . . . . Smithsonian Institute Report, Washington, D. C.
Scribner . . . Seton-Thompson pictures, Charles Scribner & Co., N. Y.
Soule . . . . Soule Art Co., 338 Washington Street, Boston.
T. P. . . . . The Tabor-Prang Co., Springfield, Mass.
T. . . . . Earl Thompson & Co., Syracuse, N. Y.
T. B. . . . . Thompson blue prints: 4 x 5, $1 per hundred; 8 x 10, 10 cts. each; 16 x 20, 20 cts. each.
T. S. . . . . Silver prints: 4 x 5, 10 cts.; 8 x 10, 25 cts.; 16 x 20, $1.
T. P. . . . . Platinum prints: 4 x 5, 25 cts.; 8 x 10, 50 cts.; 16 x 20, $2.

W. . . . . The J. C. Witter Co., 26 W. 33d St., N. Y.
W. Photo. . . Witter, 20 x 25, 25-ct. photo prints.
Wil. . . . . Mrs. Lucy Wilson's books (2 vols.) on Picture Study in the Elementary School will be referred to many times. It is published by the Macmillan Co., New York. 90 cts. each.
Woodbury . . Woodbury reproductions, E. & J. B. Young & Co., 9 W. 18th St., N. Y.

I. Animal Life

1. DOMESTICATED ANIMALS

A. Camels

SUBJECT	ARTIST	PUBLISHER
Camel		P. 1.
Camel Running		H. 1.
Camel Loaded.		H. 1.
Camel on the Desert		H. 1.

B. Cats

A Fascinating Tale . .	Ronner	Wil. II.
Left Outside	Richter	W. Photo.
Four Kittens	Adam	P. 1, 5, ½; B. 1; Cosmos.
Kittens	Berger	Hanf. C. & F.
The Cat Family . . .	Adams	P. 1, ½; B. 1; Hanf. C. & F.; Soule Sepia Carbon 20 x 24, $5; Wil. I.
A Study of Cats . . .	Lambert	B. 1; P. 1, ½; Prang 5.
To the Right into Line .	Lambert	B. 1.
Old Woman and Cats .	Knaus	P. 1.
Cats and Kittens . . .	. . . . .	P. 1, ½.
Four Little Scamps . .	Adam	H. Carbonettes, 4 x 5; P. 1, 5; Cosmos.
The First Move . . .	Henrietta Ronner .	Braun, 14 x 18, $4; 8 x 10, $1.50.
Exact Time	Henrietta Ronner .	Braun, 11 x 18, $4; 8 x 10, $1.50.

Platinum Prints of cats, copyrighted by Byerbulard, can be obtained from various Art Stores.

A large number of pictures of cats and kittens can be obtained in the P. 1 and Au. 40 ct. prints.

C. Cattle

SUBJECT	ARTIST	PUBLISHER
Cows at Watering Place	Auguste Bonheur	B. 1; T. B.; T. S.; T. P.
Study of Cows	Barillot	B. 1.
Cattle	Paul Potter	P. 1; B. 1; T. B.; T. S.; T. P.
The Prize Calf	Landseer	B. 1; P. 1.
The Return to the Farm	Troyon	P. 1; B. 1; Cosmos.
Cattle in a Marsh	Von Marcke	B. 1; T. 10 x 13, $2.50; Wil. I.
Landais Cattle	Von Marcke	B. 1.
Portrait with Head of Bull	Rosa Bonheur	B. 1.
In the Open Country	Dupré	Wil. I.
Weaning the Calves	Rosa Bonheur	P. 1, 5; Cosmos.
Landscape with Cattle	Albert Cuyp	Hanf. C. & F. & R.
Oxen Going to Their Work	Troyon	Wil. I.; B. 1; P. 1, 5; Prang 5; W. Carbon 25 x 36, $15.
The Farm Yard	Roll	B. 1; Wil. II.
Autumn Oats	Inness	W. Photo.
Plowing in Nivernais	Rosa Bonheur	B. 1; P. 1; Wil. II.; Braun, 14 x 18, $4; 8 x 10, $1.50; E. II, III & IV; Au. 28 x 35, $10.
The Young Bull	Paul Potter	T. B.; T. S.; T. P.; Wil. I; E. F.; E. R.; E. I.; B 1; P. 1; Hanf. C. F., R. I.
Wild Cattle at Chillingham	Landseer	B. 1.; P. 1; E. 28 x 38, $5.
Scotch Cattle	Wm. Watson	W. Photo Prints, 25 cts.; E. 30 x 40, $2.25.
Cows at the Lake	Voltz	Hanf. C., R. & I.
Home-going Cattle	A. Braithe	Hanf. C. F., R. & I.
Cows and Pigs	Paul Potter	Hanf. C. F. & R.
The Watering-Place	Bertram Priestman.	*I. S.*, July, 1900.
Country with Cattle	Paul Potter	Hanf. C. F. & R.
Resting Cattle	Paul Potter	Hanf. R.; T. B.; T. S.; T. P.
Homeward	Arnesby Brown	*I. S.*, Oct., 1900.
A Dutch Study	Mauve	F., $1.
Road to the Village	Riecke	Soule.
Jersey Cow		H. 1; Cosmos.

SUBJECT	ARTIST	PUBLISHER
"The Runaway" . .	. . . . .	H. 1; Cosmos.
The White Cow . . .	Jules Dupré . . .	T. B.; T. S.; T. P.; Braun, 14 x 18, $4; 8 x 10, $1.50.
Landscape with Cattle .	Thompson . . .	C. 9 x 12, $3; 7 x 9, $1.50.
Resting Cattle . . .	Johnson	C. 6 x 13, $2.50.
Team of Oxen . . .	Rosa Bonheur . .	H. 28 x 35 $4; Braun, 8 x 10, $1.50.
The Prairie	Julien Dupré . . .	Braun.
The Valley of Arques .	Julien Dupré . . .	Braun.
Return from the Field .	Ed. Debat-Pousan .	Braun.
The Drinking Pool . .	Ed. Debat-Pousan .	Braun.
Milking Time . . .	. . . . .	Cosmos.
Brittany Cattle . . .	Rosa Bonheur . .	Cosmos.
Weaning the Calves .	Rosa Bonheur . .	Cosmos.
Oxen Going to Labor .	. . . . .	Cosmos.
Holland Cattle . . .	. . . . .	Cosmos.
The Bull	. . . . .	Cosmos.

D. Dogs

Hounds in Leash . . .	Brenton	Wil. I; Cosmos.
Dignity and Impudence	Landseer	Hanf. R.; B. 1; P. 1; E., 24 x 29, $3; Cosmos; T. B.; T. S.; T. P.; Braun, 14 x 18, $4; Woodbury.
My Dog	Landseer	P. 1; B. 1.
Saved	Landseer	P. 1; B. 1; Cosmos.
Sleeping Bloodhound .	Landseer	Braun, 14 x 18, $4; B. 1; P. 1.
St. Bernard Dog . . .	. . . . .	P. 1.
A Scratch Pack . . .	Barber	B. 1.
Dog	. . . . .	S.
Bayard	F. Paton	B. 1.
Eclipse (head) . . .	F. Paton	B. 1.
Waiting for Breakfast .	Schmitzberger . .	B. 1.
A Day with the Oakley .	Thomas Blinks . .	Ber. Photographs, 26 x 33½, $4; 15 x 20, $1; Photogravures, 13 x 21, $5.
King Charles' Spaniels .	Landseer	H. 1; Braun, 14 x 18, $4.
A Wolf-Dog	Paul Potter . . .	Cosmos; Braun, 14 x 18, $4.
Highland Dogs . . .	Landseer	Woodbury.

E. Goat

SUBJECT	ARTIST	PUBLISHER
Goat		S.
Mountain Goat		Scribner.
Angora Goat		D. of A. Bul. 27.

F. Horses

A Kabyl	Schreyer	Wil. I; Prang 5; B. 1; P. 1.
The Horse Fair	Rosa Bonheur	Wil. II; P. 1, 5, ½; B. 1; E., 26 x 42, $12; Prang 5; Hanf. R. & I.; W. Au.; Carbon Photo, 28 x 28, $5; 22 x 28, $2.25; T. B., S. & P.; Cosmos.
The Watering-Trough	Dagnan-Bouveret	Cosmos; Wil. II; B. 1; P. 1; Prang 5; W. Photo.
Shoeing a Bay Mare	Landseer	B. 1; P. 1; Hanf. R.; E. R.; E. I.
A Distinguished Member of the Humane Society	Landseer	E. I.; E. F.; Hanf. R.
Pharaoh's Horses	J. F. Herring	P. 1, ½; *N. S.*, March, 1901; W. Photo; E., 30 x 30, $2.25; B. 1; T. P.; T. S.; T. P.
Waiting for Mistress	Landseer	*N. S.*, March, 1901.
Coming from the Fair	Rosa Bonheur	P. 1; B. 1; Cosmos.
Three Members of a Temperance Society	Herring	*N. S.*, March, 1901; B. 1; Cosmos.
Resting Horses	L. Hartman	Hanf. C. F. & R.
Labourers	Arnesby Brown	*I. S.*, Oct., 1900.
Wood Cutters	Anton Mauve	F., $1.
The Arabian Chargers	Schreyer	C., 16 x 20, $6; 8 x 13, $3; 6 x 9, $1.50; Cosmos.
In the Normandy	Jules Jacques Veyrasset	Braun, 14 x 18, $4; 8 x 10, $1.50.
Percheron Horses	Jean Richard Gombie	Braun, 14 x 18, $4; 8 x 10, $1.50.
On the Borders of the Marsh	George Maroniez	Braun, 14 x 18, $4.
Horse		S.; *C. L.*, Dec., 1901.

G. Sheep

SUBJECT	ARTIST	PUBLISHER
Sheep	Mauve	W. Platinums, 8 x 10, 75 cts.; 10 x 13, $1.75; P. 1, 5.
Art Critics	O. Gebler	B. 1; Ber., $1, $4.
The Sheep Fold	Charles Jacque	W. Platinum, 9 x 14, $1.50; Wil. II; B. 1; P. 1, ½; E., 33 x 43, $5.
Shepherdess	Le Rolle	B. 1; Wil.; P. 1, 5; Prang 5; W. Carbon, 28 x 38, $5; 22 x 28, $2.25; W., 25 cts.; Photo Prints, 20 x 25; H. 1.
Sheep Autumn	Mauve	P. ½, 1; F., $1; Cosmos.
Sheep Spring	Mauve	P. ½, 1; F., $1; Cosmos.
Brittany Sheep	Rosa Bonheur	W. Photo; Wil. I; B. 1; P. 1; Cosmos; H., 28 x 35, $4.
The Contented Flock		Cosmos.
Landscape with Sheep	Charles Jacque	L., 7½ x 9½, $2; 10 x 13, $3.
Lost	Schenck	F.; W. Photo.
Sheep Shearing	Millet	B. 1; P. 1.
Sheep in Pasture	Auguste Bonheur	B. 1.
The Return to the Farm	Troyon	B. 1; P. 1; Wil. I.
The Return to the Sheep Fold		Cosmos.
Shepherdess Knitting	Millet	B. 1; P. 1; Prang 5; F., 12 x 17, $4; C., 8 x 12, $3; 6 x 9, $1.50; Cosmos.
On the Southdowns	James Aumonier	*I. S.*, Sept., 1900.
In Charge of the Flock	Mauve	C., 6 x 9, $1.50; 10 x 12, $3; 16 x 20, $6 (colored); 9 x 12, $6; 16 x 20, $12; F., $1.
Sheep Washing	James Aumonier	*I. S.*, Sept., 1900.
The Lost Sheep	Charles Jacque	C., 6 x 13, $2.50; 4 x 9, $1.25.
Evening	Mauve	F., $1; P. 5.
A Flock of Sheep	Mauve	F., $1; Cosmos.
The Return of the Flock	Millet	L., 7½ x 9½, $2; 10 x 13½, $3; F. 1.
Highland Sheep	Rosa Bonheur	L., 6¾ x 9¼, $1.50; 9¼ x 13, $2.50; Braun, 14 x 18, $4.

SUBJECT	ARTIST	PUBLISHER
Sheep in Pasture	Auguste Bonheur	T. B.; T. S.; T. P.
Down the Lane by Twilight	Wiggins	C., 13 x 10, $2.50.
In the Fold	Henry Troth	*L. H. J.*, May, 1901.
Sunset Glow	Riecke	Soule.
Sheep		*C. L.*, Nov., 1901; Steiger's Chart.
Midsummer Day	Lumputten	F.

2. WILD ANIMALS

Pictures of the common birds may be found in colors among the two-cent Perry pictures and the twenty-five cent Prang (11 x 14) pictures.

Colored pictures of other animals may also be found among the two-cent Perry illustrations, but these are not of much value, although they have been mentioned in this outline where no better was known.

Steiger & Co. publish a number of colored charts of wild animals, many of which are good as regards structure, but the coloring is sometimes harsh.

A set of twelve animal pictures by Ernest Seton-Thompson is published by Charles Scribner & Co. $6 for the set or 60 cts. each.

The following list is somewhat miscellaneous in character, and gives comparatively few illustrations out of the large number that might be mentioned.

SUBJECT	ARTIST	PUBLISHER
Antelope	Seton-Thompson	Scribner.
Baboon		P. 2; M. 2.
Bear (head)	Seton-Thompson	Scribner.
Bear and Cubs	Seton-Thompson	Scribner.
Bear and Cub (Johnny)	Seton-Thompson	Scribner.
Bear Pictures	Seton-Thompson	*C. Mag.*, 1900.
Bear (black)		H. 1; M. 1.
Bear (white)		*M. Mag.*, April, 1901.
Bison (head)	Seton-Thompson	Scribner.
Boar		M. 2; A.
Beaver	Photo Reproductions	*E. Mag.*, March, 1901.
Beavers' House	Photo Reproductions	*N. S.*, March, 1901.
Beavers	Photo Reproductions	*E. Mag.*, April, 1901.
Beaver	Photo Reproductions	*E. Mag.*

SUBJECT	ARTIST	PUBLISHER
Coyote	Seton-Thompson	Scribner.
Deer		A.; S.
The Monarch of the Glen	Landseer	B. 1; P. 1.
The Deer Pass		Cosmos.
Red Deer of Chillingham	Landseer	B. 1; P. 1.
Wild Deer	Hein	W. Photo.
A Highland Lassie and Fawns	Landseer	P. 1.
A Deer Family	Landseer	P. 1.
Fawn	Remington	H. 1.
Stag Feeding	Kröner	Ber., 8 x 10, $1.
Reindeer	Frost	H. 1.
Moose Deer	Frost	H. 1.
Moose Deer	Remington	H. 1.
Elephant		*E. Mag.*, April, 1901; P. 1.
Elephant Hunt		H. 1.
Elephant Ride		H. 1.
Fox		S.; P.
Young Foxes	Carter	B. 1.
Mother and Young Foxes	Seton-Thompson	Scribner.
Arctic Foxes		H. 1; A.
Giraffe		P. 1; A.; S.
Giraffe		S.; P. 1; A.
Gopher		P. 2.
Ground Hog		P. 2.
Hare		P. 2; M. 2.
Hippopotamus		P. 1; A.
Jaguar		P. 1; H. 1; A.
Kangaroo		H. 1; P. 2; A.; S.
Leopard		A.; P. 1.
Lion		H. 1; S.; Woodbury.
An Old Monarch		Cosmos.
Lion and Lioness		Cosmos; T. B.; T. S.; T. P.
Head of an Asiatic Lion		P. 2; O., 8 x 10, $1.50.
Study of a Lion	Landseer	E., 19 x 25, $3.
Study of a Lioness	Bonheur	Braun, $4.
Lion at Home	Bonheur	B. 1; P. 1; T. B.; T. S.; T. P.
African Lion		P. 2; A.
Mole (common)		P. 2.
Mink		P. 2.

SUBJECT	ARTIST	PUBLISHER
Muskrat		P. 2.
Rabbit		P. 1; S.
Rabbits	Fisher	H. 1; Hanf. C., F. & R.
Rabbit	Durer	B.
Raccoons	Seton-Thompson	Scribner.
Rhinoceros		P. 1; H. 1; A.
Squirrel		H. 1; *E. Mag.*, April, 1901.
Tiger		P. 1; A.; S.
Tiger	Hunt	P. 1.
An Interrupted Feast	Church	M. 1; H. 1; T. B.; T. S.; T. P.
Wolf		H. 1; A.
Zebra		P. 1; A.

II. Plant Life

A set of three pictures published originally by the Chicago Photo Reproduction Co., and now sold by the Perry Picture Co., are very excellent. On each sheet there is a picture of the tree, a spray of leaves and portion of the trunk to show the bark.

The Lewis Leaf Charts are also valuable, and may be obtained from all dealers in school supplies.

Among the illustrations in government publications, the following will be found most excellent:

Practical Forestry in the Adirondacks. D. of A., Div. of Forestry, Bul. 26.

The Forest Conditions of Porto Rico. D. of A., Div. of Forestry, Bul. 25.

Big Trees in California. D. of A., Div. of Forestry, Bul. 28.

The White Pine. D. of A., Div. of Forestry, Bul.

By applying to the Secretary of Agriculture, a monthly list of publications will be forwarded, and from this list selections of papers may be made. All Farmers' Bulletins are furnished free.

Cornell University publishes Nature Study leaflets for teachers free of charge.

A useful one in studying the oak tree is

The Leaves and Acorns of Our Common Oaks. Cornell Leaflet, Bul. 8.

Most plant life can be studied directly from portions of or the entire growing plant, so that illustrations have not the same value for this part of the nature work that they have for animal study.

III. Industries

1. *Baker*

SUBJECT	ARTIST	PUBLISHER
Baker		Prang, 22 x 14 (colored), 50 cts.

2. *Blacksmith*

Village Blacksmith	Herring	B. 1; P. 1; *N. S.*, March, 1901.
Blacksmith	Frere	P. 1.
Shoeing a Bay Mare	Landseer	B. 1; P. 1; Hanf. R.; Braun, 14 x 18, $4.
The Blacksmith	Philip Wouvermann	T. B.; T. S.; T. P.
Blacksmith		Prang, 22 x 14, 50 cts. (colored).
Blacksmith Ready for Welding	Henry Sandham	F.

3. *Carpenter*

Carpenter		Prang, 22 x 14, 25 cts. (colored).

4. *Farm Life*

The Gleaners	Millet	Braun, 8 x 10, $2; 14 x 18, $4; P. 1, 5, ½; Prang; B. 1; Wil. II; E. II, III, IV; W. Carbon, 28 x 28, $2.25; W. Photo Prints, 25 cts.; Cosmos; T. B.; T. S.; T. P.
The Balloon	Jules Dupré	W. Photo; Wil. I; B. 1; P. 1, ½; H.
The Haymaker	Adam	H., 28 x 35, $4; Braun, 14 x 18, $4; 8 x 10, $1.50; Wil. I; Au. 19 x 14½, 40 cts.

SUBJECT	ARTIST	PUBLISHER
The Gleaners	Breton	H., 28 x 35, $4; E. II, III & IV; Au., 28 x 35, $10; Braun, 14 x 18, $4; 8 x 10, $1.50; B. 1; P. 1, 5, ½; T. B.; T. S.; T. P.
The End of Labor	Breton	P. 1; Au. $10; Braun, 24 x 30, $15; 14 x 18, $4; 8 x 10, $1.50.
The Angelus	Millet	B. 1; P. 1, 5, ½; Wil. II; E. II, III; W. Platinum, 8 x 10, 75 cts.; 10 x 13, $1.75; W. Photo Prints, 25 cts.; Braun, 14 x 18, $4; T. B.; T. S.; T. P.
Spring	Millet	Wil. II; Braun, 8 x 10, $2; 14 x 18, $4.
The Sower	Millet	Wil. II; P. 1, 5; B. 1; T. B.; T. S.; T. P.; W. Photo; F. Water colors and drawing, 75 cts.; Braun, 8 x 10, $2.
The Mowers	Dupré	Cosmos.
The Man with the Hoe	Millet	B. 1; P. 1, 5, ½; E. II; W. Photo; Braun, 14 x 18, $4.
The Shepherdess	Millet	E. II, III; W. Carbon, 28 x 28, $2.25; Braun, 24 x 30, $15; 14 x 18, $4.
Haying Time	Julien Dupré	E., 27 x 40, $2.25; Braun, 14 x 18, $4; 8 x 10, $1.50.
The Song of the Lark	Breton	H. 1; E. II, III, IV; Wil I; W. Carbon, 28 x 28, $2.25; H., 28 x 35, $4; W. Photo; Braun, 24 x 30, $15; 14 x 18, $4; B. 1; P. 1, 5.
The Cornfield	John Constable	E. I.
In the Country	H. Lerolle	E. II, III, IV; W. Carbon, 13 x 17, $4.
Autumn Oaks	Inness	W. Photo.
Spring Time	Daubigny	W. Platinum, 8 x 10, 75 cts.; 10 x 13, $1.75.
A Summer Day	Breton	C. 16 x 20, $6.00; 9 x 13, $2.50; 6 x 9, $1.50.

SUBJECT	ARTIST	PUBLISHER
Feeding the Hens	Millet	B. I; P. 1; Wil. I.
Woman Churning	Millet	Wil. I; B. 1; P. 1, 5.
The Harvest Time	L'Hernutte	Wil. I; B. 1; P. 1.
The Reapers	Breton	B. 1.
Farmyard, Normandy	Roll	B. 1; Wil. II.
Farmyard	Herring	B. 1.
Setting up Sheaves	George Clausen	*I. S.*, July, 1900.
Brittany Farmhouses	Corot	F. Platinum, 10 x 13, $2.
The Wood Chopper	Mauve	F. $1.
Brittany Kitchen	Theo. Robinson	F. Platinum, 7 x 13, $2.
The Farm at Barbizon	Rousseau	L. 5½ x 9½, $1.75; 8¼ x 13½, $2.75.
The Close of Day	Adam	Braun, 14 x 18, $4; 8 x 10, $1.50; Au. 11 x 17½, $1.50; H. 28 x 35, $4.
The Hayfield	Arnesby Brown	*I. S.*, Oct., 1900.
Graphic (cutting hay)	Ruth Robinson	*I. S.*, Oct., 1900.
A Barnyard Scene	Burdett Frost	H. 1.
The Farmyard	Paul Potter	Ber. 7 x 10, $2.
The Reapers	Hans Olde	*I. S.*, Nov., 1900.
Erute (cutting hay)	Hans Olde	*I. S.*, Nov., 1900.
Rustic (loading wheat)	Hans Olde	*I. S.*, Nov., 1900.
Summer Evening	Alphonse Stengelin	Braun, 14 x 18, $4.
Return of the Harvester	Jules Breton	Braun, 14 x 18, $4.
The White Cow (milking.)	Julien Dupré	Braun, 14 x 18, $4; 8 x 10, $1.50; H. 28 x 35, $4.
Before the Storm (loading hay)	Julien Dupré	Braun, 14 x 18, $4; 8 x 10, $1.50.
The Haymakers	Rosa Bonheur	Braun, 24 x 30, $15; 14 x 18, $4; 8 x 10, $1.50.
Daughter of the Fields	Jules Breton	Braun, 14 x 18, $4; 8 x 10, $1.50.
The Fire Alarm (In the hay field)	Jules Breton	Braun, 14 x 18, $4; 8 x 10, $1.50.
In the Corn Field; or, Country Lane	John Constable	Au. 16½ x 14½, $1.50.
The Valley Farm	John Constable	Au. 14 x 17, $1.50.
The Hay Field		*C. L.*, Nov., 1901, Dec., 1901.
Ranch Life (4 pictures)		D. of A. Bul. 62, 1899.
Gardening		Prang, 22 x 14, 50 cts.
Farm Yard		Prang, 22 x 14, 50 cts.
Haymaker		Prang, 22 x 14, 50 cts.
Storing and Keeping Fruits and Vegetables		*C. L.*, Dec., 1901.
The Farm Yard		S. 54 x 36, $2.50.

5. *Fishing*

SUBJECT	ARTIST	PUBLISHER
Return of the Fishers	Feyer-Perrin	B. 1.
Return of the Oyster Fishers	Feyer-Perrin	B. 1.
A Helping Hand	Renouf	Wil. I; B. 1; P. 1.
Hauling in the Nets	Georges Haquette	Au. 12 x 18½, $1.50.
Herring Boats	Mary McCrossan	*I. S.*, Nov., 1900.
Fisherman Returning Home	Fr. Smith-Hald	Ber. Photogravure, 13 x 20, $5.
Outward Bound	Georges Haquette	Braun, 8 x 10, $1.50; H. 28 x 35, $4.
Departure of Fishermen	Georges Haquette	Au. 11 x 18½, $1.50.

6. *Lithographer*

Development of the Book (4 different pictures taken from the National Library at Washington.)	Alexander	C.
Lithographer		Prang.

7. *Lumbering*

The Wood Chopper	Millet	P. 1.
Logging	Anton Mauve	F. $1.
Wood Cutters	Anton Mauve	F. $1.
Spruce Skids Left in the Woods		D. of A. Div. of Forestry, Bul. 26, Plate XIX.
Waste in Lumber		D. of A. Div. of Forestry, Bul. 26, Plates XVII, XVIII, and XX.
Small Spruce Used in Leveling a Lumber Road		D. of A. Div. of Forestry, Bul. 26, Plate XVIII.
Large Logs		D. of A. Div. of Forestry, Bul. 26, Plate XII.
Good and Bad Cutting		D. of A. Div. of Forestry, Bul. 26, Plate II.

SUBJECT	ARTIST	PUBLISHER
Logging		*N. E.*, Jan., 1901.
California Trees		*C. L.*, Supplement, Dec., 1901.
Logging Railroad in a Big Tree Forest		D. of A. Div. of Forestry, Bul. 28, Plate XIII.
Hauling Big Tree Saw Logs on a Log Slide with Ten Mules		D. of A. Div. of Forestry, Bul. 28, Plate XII.
Ten Men Felling a Big Tree with Axes		D. of A. Div. of Forestry, Bul. 28, Plate XI.
	8. *Milling*	
The Water Wheel	Hobbema	W. Carbon, 28 x 28, $2.25; H. 28 x 35, $4; Hanf. C, F, R, I.
The Mill	Ruisdael	E. F.; E. I.; Hanf. F. R., I. & E.
The Mill	Rembrandt	Wil. II.
Saw Mill	Allart van Everdinger	Hanf. R.
The Windmill	John Crome	E. 14½ x 17, $1.50.
	9. *Printing*	
Printing		Prang, 22 x 14, 50 cts. (colored).
	10. *Shoemaker*	
Shoemaker		Prang, 22 x 14, 50 cts. (colored).
	11. *Spinning*	
Marguerite at the Wheel		T. B.; T. S.; T. P.
Saint Elizabeth Spinning for the Poor	Marianne Stokes	*I. S.*, May, 1900.
	12. *Tailor*	
Tailor		Prang, 22 x 14, 50 cts. (colored).
	13. *Tinsmith*	
Tinsmith		Prang, 22 x 14, 50 cts. (colored).

IV. Primitive People

1. *Primitive People*

SUBJECT	ARTIST	PUBLISHER
Primitive Life in the Far West		*C. Mag.*, Jan., 1902.
Indian Babies		*L. M.*, Jan., 1901.
Indians		*E. Mag.*, Jan. and Feb., 1901; *L. Mag.*, Dec., 1901; R. 1200 subjects from 40 different tribes. C. 9½ x 8½, $1.25.
The People of the Farthest North		*E. Mag.*, Jan. 1902.
Primitive People Mound Builders Indians Eskimoes, etc.		Eth. 2d, 6th, 9th, 13th and 16th Annual Reports.

2. *Primitive Industries*

Basketry		*L. Mag.*, Dec. 12, 1901.
Primitive People in the Far West		*C. Mag.*, Jan., 1902.
Development of the Book	Alexander	C.
Man at Work (weaving)		*P. I.*, Feb., 1901.
Making of the Navajo Blanket		*E. Mag.*, Jan., 1902.
Industry	Vesper L. George	F.
Indian Pottery		*O. Mag.*, Nov.; Eth.
An Indian Weaver	Geo. de Forest Brush	H. 1.
Attelage Basque	Stanhope Forbes	*I. S.*, May, 1901.

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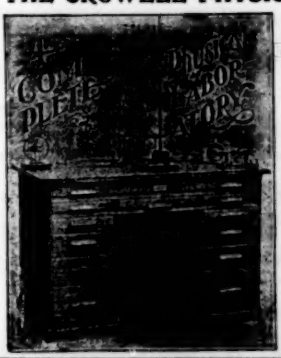

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